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CALCULATED WIND-TUNNEL-BOUNDARY LIFT-INTERFERENCE FACTORS FOR RECTANGULAR PERFORATED TEST SECTIONS

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16. Abstract

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SUMMARY

Equations developed and presented in NASA Technical Report R-285 for approximating the spanwise distribution of wind-tunnel-boundary interference on lift of wings in rectangular perforated-wall test sections are modified slightly to facilitate machine calculations and are then used to generate extensive tables of interference factors for a variety of wind-tunnel and wing parameters. Data are presented for horseshoe-vortex representations of small-span and large-span wings mounted at the center of rectangular test sections with five values of tunnel width-height ratio varying from 0.5 to 2.0 and with the ratio of permeability factor to compressibility factor ranging from 0.1 to 25.0. Spanwise distributions of upwash interference factor are given for each case. Use of the tables requires knowledge of the values of permeability factor applicable to the perforated test section for which lift interference factors are desired. Machine computer programs used in the calculations are presented as an appendix.

INTRODUCTION

During the last two decades, a number of wind tunnels have been constructed with test sections having perforated walls. Such walls are of particular advantage in testing through sonic speeds and at speeds slightly supersonic because they may reduce the severity of shock-wave disturbances reflected from the walls and impinging on the test models. However, these wind tunnels are commonly used also for subsonic testing, and if winged models are of appreciable size relative to the cross section of the tunnel at the test location, it is desirable to correct for the modification of test conditions due to the upwash interference of the tunnel boundaries.

For constructional and operational convenience and for avoidance of focusing of reflected shocks in the transonic speed range, perforated-wall test sections are commonly made rectangular in cross section. An approximation method for estimating the wind-tunnel-boundary upwash interference along the span of a lifting wing mounted at the center of such a perforated-wall test section was developed in reference 1. However, the extensive calculations required to obtain numerical values of upwash interference factors

involve the numerical evaluation of multiple infinite integrals containing integrands singular at the zero point of the domain of integration. In order to facilitate the application of the theory of reference 1, machine computing programs for calculation of upwash factors were prepared and are presented herein along with tables of upwash factors applicable to a range of practical configurational and operational parameters. Figures constructed from the tables illustrate the variation of upwash interference factor with effective permeability of the test-section walls, with spanwise location along the wing, and with ratio of width to height of the test section. Although the theory of reference 1 provides for the possibility that the permeability of the top and bottom walls is different from that of the side walls, it is assumed uniform for these calculations.

SYMBOLS

A	cross-sectional area of test section
a	variable used for convenience to represent more complicated expression in equation (A12)
b	semiwidth of test section
C_L	lift coefficient

$$\left.\begin{array}{l} F_i(q), F_i'(q) \\ G(q,r), G'(q,r) \\ G_i(q,p), G_i'(q,r), G_i''(q,r) \\ K_i(q,r), K_i'(q,r) \\ H(q,r,p), H'(q,r,p) \\ H_i(q,r,p), H_i'(q,r,p), H_i''(r,\rho,\theta) \\ H_{i,j}(q,r,p), H_{i,j}'(q,r,p), H_{i,j}''(r,\rho,\theta) \\ L_i(q,r,p), L_i'(q,r,p) \\ L_{i,j}(r,\rho), L_{i,j}'(r,\rho) \end{array}\right\} \text{Symbols used for convenience to represent functions of the indicated dummy variables}$$

h	semiheight of test section
M	Mach number

p,p'	dummy variables of integration
q	dummy variable of integration
R	permeability factor
r	dummy variable of integration
S	area on which lift coefficient is based
s	semispan of horseshoe vortex representing wing
V	velocity of tunnel test stream
v	upwash interference velocity, positive in direction of Z-axis
X,Y,Z	axes of rectangular Cartesian coordinates
x,y,z	rectangular Cartesian coordinates, x in direction of tunnel flow, y along direction of wing span, and z vertical

$\beta = \sqrt{1 - M^2}$

Γ	circulation
δ	upwash interference factor
θ	dummy variable of integration
ρ	dummy variable of integration

Subscripts:

The subscript j is used as a secondary subscript only as a bookkeeping device. The subscript i is used as a primary subscript with the following definitions:

2	pertaining to vertical boundaries
3	pertaining to horizontal boundaries

4 pertaining to effect of horizontal boundaries on interference potential inside test section due to vertical boundaries

5 pertaining to effect of horizontal boundaries on interference potential outside test section due to horizontal boundaries

UPWASH INTERFERENCE APPROXIMATION EQUATIONS

Approximation equations for calculating the upwash interference velocity v due to the boundaries of a perforated wind tunnel along a wing mounted at the center were derived in reference 1. The wind tunnel was assumed rectangular with semiheight h and semiwidth b, and the wing was represented by a horseshoe vortex with span $2s$ and circulation Γ. A rectangular Cartesian coordinate system was used with coordinates z positive in the direction of lift, y lying along the wing span, and x positive downstream in the direction of the trailing vortices. A schematic diagram showing the relationships between the various parameters is given in figure 1.

The equations of interest in reference 1 are equations (A14), which gives the interference velocity due to infinite vertical boundaries; equation (B10), which gives the interference velocity due to infinite horizontal boundaries; and equations (C10) and (C12), which give increments of interference velocity to satisfy more nearly the boundary conditions when both horizontal and vertical boundaries are present. These equations involve the permeability factors R_2 along the vertical boundaries and R_3 along the horizontal boundaries. If $R_2 = R_3 = R$; that is, if the permeability factor is assumed uniform and equal on all boundaries, then the equations approximating the various components of the interference velocity can be written in terms of R/β (where $\beta = \sqrt{1 - M^2}$ and M is Mach number) instead of separately in terms of R_2, R_3, and β.

The upwash interference factors δ_i, which are obtained from their respective upwash interference velocities by the relationship

$$\delta_i = \frac{Av_i}{SVC_L}$$

can be put in the form

$$\delta_i = \frac{b/h}{s/h} \frac{h}{\Gamma} v_i \tag{1}$$

from which the total upwash interference factor is calculated as

$$\delta = \sum_i \delta_i \tag{2}$$

The four equations referred to in reference 1 have been rewritten by means of equation (1) to give their respective upwash interference factors. These have also been rewritten so that the terms R and β never appear singly, but always appear in the form R/β. Finally, the equations have been rearranged and transformed to the extent necessary to present them in forms more readily adaptable to machine calculations. The details of these manipulations are given in appendix A. The machine computer programs are presented in appendix B.

RESULTS AND DISCUSSION

As mentioned in the preceding section, the approximation equations have been rewritten so that the upwash interference factors are expressed in terms of R/β rather than singly in either the permeability factor R or in β. For the purposes of calculation, β was allowed to take the values 1.0, 0.8, 0.6, 0.45, and 0.3 for each of the values of R, which were 0.1, 0.45, 2.0, and 7.5. Thus, upwash interference factors were calculated for 20 values of R/β ranging from 0.1 to 25.0. The calculations were made for this range of R/β for each of five different values of tunnel width-height ratio b/h, which were 0.5, 0.75, 1.0, 1.5, and 2.0, for both a small-span wing (s/b = 0.3), where s/b is the ratio of wing span to tunnel width, and a large-span wing (s/b = 0.7). Finally, the interference factors were calculated for three locations along the wing span (y/s = 0.0, 0.5, and 1.0) for each value of the parameters s/b, b/h, and R/β.

The resulting calculated upwash interference factors for a small-span wing mounted in the center of a rectangular perforated wind tunnel are presented in table I. Each page of the table presents the variation of upwash interference factors along the wing span for the entire range of R/β for one of the five values used for b/h. Table II presents the corresponding calculations for a large-span wing. Values are given for each of the individual upwash interference factors δ_2, δ_3, δ_4, and δ_5 (as defined by eq. (1) in conjunction with subscript definitions in the list of symbols) as well as for the total upwash interference factor δ.

There is always the possibility of calculation errors (such as round-off errors) in calculations of this type, and a certain amount of effort is required to ascertain the extent of these errors in order to decide what level of confidence to place in the final calculations. The infinite integration limits in these particular calculations necessitated an arbitrary truncation of the calculating procedure beyond a certain point in order to conserve computer time. To some extent with the double integrals, and especially with the triple integrals, compromises had to be made between the level of accuracy desired and the calculating time used. Therefore, the integration range was broken up into small equal intervals the lengths of which were chosen from information obtained in preliminary

computer runs of the program. Integrations were then made successively over each of the intervals, the integration limits increasing by the interval length with each integration step. When the integral over the last interval was less than some arbitrarily chosen small number (a change of one unit in the fifth decimal place in this case), the integral was assumed to have converged and the integration procedure was terminated. In these calculations, the rapid approach of the integrands toward zero with increase of the integration variables lent credence to this criterion of convergence.

The accuracy of machine calculations also depends upon the number of points per integration interval used in the machine integration routine (the Gaussian quadrature method was used for these calculations). Here, again, compromises had to be made between desired accuracy and calculating time. For the calculations herein, the number of points used was increased over several preliminary runs of the program, and the final number of integration points chosen was that for which the value of the integral changed by no more than one unit in the fifth decimal place between successive trials with increasing numbers of points.

Special consideration and handling must be given to integrals whose integrands contain terms causing the integrands to oscillate about zero as the integration variable increases. In several instances in the integrals reported herein (as discussed in appendix A), the integrands contained products of sines and cosines whose arguments contained the same variable but differed in the constants by which the variable was multiplied. Thus, several terms in the integrand were oscillating about zero at different frequencies. This behavior indicates the possibility that oscillations might combine within some particular integration interval in such a way as to cause the integral over that interval to be very small. The calculation process might then be truncated prematurely because of a spurious indication of convergence of the integral. The approach used in handling this problem was to combine the sine-cosine product terms by means of multiple-angle trigonometric identities into sums of sine and cosine terms whose arguments were the same and then to choose the integration interval to extend over some multiple of a half-cycle of the new argument. Tables I and II present data only to three decimal places, but the tests on convergence and number of points per integration interval were to five decimal places; therefore, the values in the tables are assumed free of arithmetic truncation errors.

If the approximation equations for the various components of upwash interference factors are valid, then the total upwash interference factors should approach the values for the completely closed tunnel as R/β approaches zero and the value for the completely open tunnel as R/β becomes very large. Such behavior is confirmed by the curves of figure 2 which show the variation of total upwash interference factor at the center of a small-span wing mounted in the center of a rectangular perforated wind tunnel

as a function of R/β for several values of tunnel width-height ratio b/h. Figure 3 shows the corresponding curves for a large span wing, and again the calculated values tend toward the closed-tunnel values for small R/β and toward the open-tunnel values for large R/β. Note that on the logarithmic scale of figures 2 and 3, the point on the abscissa corresponding to the closed tunnel ($R/\beta = 0$) lies infinitely far to the left, and the point corresponding to the open tunnel ($R/\beta \rightarrow \infty$) lies infinitely far to the right.

The open-tunnel and closed-tunnel upwash interference factors at the center of the test section, which are given for comparison, were calculated from equations independently derived by the method of images as in reference 2. For the closed test section, δ at the center of the wing is

$$\delta = \frac{1}{2\pi \frac{b}{h}\left(\frac{s}{b}\right)^2} - \frac{\operatorname{cosech}\left(\frac{\pi}{2}\frac{b}{h}\frac{s}{b}\right)}{4\frac{s}{b}} + \frac{1}{4\frac{s}{b}}\sum_{n=1}^{\infty}\left\{\operatorname{cosech}\left[\frac{\pi}{2}\frac{b}{h}\left(2n - \frac{s}{b}\right)\right] - \operatorname{cosech}\left[\frac{\pi}{2}\frac{b}{h}\left(2n + \frac{s}{b}\right)\right]\right\} \tag{3}$$

and for the open test section, δ at the center of the wing is

$$\delta = \frac{1}{2\pi \frac{b}{h}\left(\frac{s}{b}\right)^2} - \frac{\operatorname{cotanh}\left(\frac{\pi}{2}\frac{b}{h}\frac{s}{b}\right)}{4\frac{s}{b}} + \frac{1}{4\frac{s}{b}}\sum_{n=1}^{\infty}(-1)^n\left\{\operatorname{cotanh}\left[\frac{\pi}{2}\frac{b}{h}\left(2n - \frac{s}{b}\right)\right] - \operatorname{cotanh}\left[\frac{\pi}{2}\frac{b}{h}\left(2n + \frac{s}{b}\right)\right]\right\} \tag{4}$$

Machine computer programs corresponding to these equations are given in appendix B.

Plots and cross plots made from the extensive data presented in tables I and II afford a great deal of insight into the variation of upwash interference factors with various tunnel and wing parameters. No attempt will be made in this paper to present a comprehensive set of figures showing the interrelationships of the upwash interference factors with the various other parameters. Two figures (figs. 4 and 5) illustrative of the type of information available are given. Figure 4 shows the variation of total upwash interference factor along the spans of both small-span and large-span wings for several values of R/β and for several tunnel width-height ratios. Figure 5 shows the variation of upwash interference factor with tunnel width-height ratio for several values of R/β for both the small-span and large-span wings.

A comparison of figures 4(a) and 4(b) shows that the variation of the interference along the span is small for the small-span wing but substantial for the wing spanning 0.7 of the test-section width. Also, the largest spanwise variation occurs for the test section having the smallest width-height ratio, an effect that might have been anticipated since in this case a large part of the interference is produced by the side walls. Note however, that in all cases for which the permeability is such as to produce nearly zero

interference at the center of the wing, the interference at the wing tips is also nearly zero.

Figure 5 shows that except for the nearly open tunnel with height greater than the width, the downwash interference at the center of a wing spanning a given fraction of the width of the test section increases with increase of the test-section width-height ratio.

CONCLUDING REMARKS

Equations developed in NASA Technical Report R-285 for approximating the spanwise distribution of wind-tunnel-boundary interference on lift of wings in rectangular perforated-wall test sections have been modified to facilitate machine calculations and then used to generate tables of interference factors for a variety of wind-tunnel and wing parameters.

The upwash interference factors presented in the tables are applicable only if the permeability factor R is known. Inasmuch as R depends not only on the geometry of the perforated walls but also on operating conditions such as Reynolds number, Mach number, and boundary-layer thickness, it cannot be calculated but must be experimentally determined. The effective permeability factor may also vary from place to place over the perforated walls so that the use of some average values may be required.

The approximation method used in the calculations is believed to yield upwash interference factors of adequate accuracy. Because the wing is represented by a single horseshoe vortex, the calculated upwash interference factors are applicable only to wings of reasonably small chord.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., October 16, 1969.

APPENDIX A

ADAPTATION OF UPWASH INTERFERENCE EQUATIONS TO MACHINE CALCULATIONS

Equation (A14) of reference 1, which represents the upwash interference velocity due to infinite vertical boundaries, can be rewritten by means of equation (1) in the body of the present report to give the upwash interference factor

$$\delta_2 = \frac{1}{2\pi^2}\frac{b/h}{s/h}\left[\int_0^\infty F_2(q)dq - \frac{2}{R}\int_0^\infty\int_0^\infty G_2(q,p)dp\ dq\right] \tag{A1}$$

where

$$F_2(q) = \frac{\pi \sinh\left(\frac{s}{h}q\right)\cosh\left(\frac{y}{h}q\right)}{e^{\frac{b}{h}q}\sinh\left(\frac{b}{h}q\right)}$$

and

$$G_2(q,p) = \frac{q^2\sinh\left(\frac{s}{h}\sqrt{\beta^2p^2 + q^2}\right)\cosh\left(\frac{y}{h}\sqrt{\beta^2p^2 + q^2}\right)}{\sqrt{\beta^2p^2 + q^2}\left[\frac{\beta^2p^2 + q^2}{R^2}\sinh^2\left(\frac{b}{h}\sqrt{\beta^2p^2 + q^2}\right) + p^2\cosh^2\left(\frac{b}{h}\sqrt{\beta^2p^2 + q^2}\right)\right]}$$

If the transformation of variables

$$\beta p = r\cos\theta \qquad\qquad q = r\sin\theta$$

is made in the double-integral portion of equation (A1), then the differential element $\beta\ dp\ dq$ is replaced by $r\ dr\ d\theta$ and the double integral becomes

$$\frac{2\beta}{R}\int_0^\infty \frac{\sinh\left(\frac{s}{h}r\right)\cosh\left(\frac{y}{h}r\right)}{\cosh^2\left(\frac{b}{h}r\right)}\int_0^{\pi/2}\frac{\sin^2\theta\ d\theta\ dr}{\left(\frac{\beta}{R}\right)^2\tanh^2\left(\frac{b}{h}r\right) + \cos^2\theta}$$

Rearrangement of the integral over θ by means of the double-angle trigonometric identities gives an integral in θ which can be integrated analytically. If the dummy variable of integration r is replaced by q, the result can be combined with the single-integral portion of equation (A1) to give the upwash interference factor

$$\delta_2 = \frac{1}{2\pi} \frac{b/h}{s/h} \int_0^\infty F_2'(q)\,dq \tag{A2}$$

where

$$F_2'(q) = \frac{\sinh\left(\frac{s}{h}q\right)\cosh\left(\frac{y}{h}q\right)}{\sinh\left(\frac{b}{h}q\right)} \left\{ e^{-\frac{b}{h}q} + \operatorname{sech}\left(\frac{b}{h}q\right)\left[\frac{\beta}{R}\tanh\left(\frac{b}{h}q\right) - \sqrt{\left(\frac{\beta}{R}\right)^2 \tanh^2\left(\frac{b}{h}q\right) + 1}\right]\right\}$$

In the limits, as the permeability factor R approaches zero (closed-tunnel case) and infinity (open-tunnel case), equation (A2) approaches the same limits as those obtained in reference 1.

The upwash interference velocity due to infinite horizontal boundaries, given by equation (B10) of reference 1, is written in terms of the upwash interference factor as

$$\delta_3 = \frac{1}{2\pi^2} \frac{b/h}{s/h}\left[\int_0^\infty F_3(q)\,dq - \frac{2}{R}\int_0^\infty\int_0^\infty G_3(q,p)\,dp\,dq\right] \tag{A3}$$

where

$$F_3(q) = \frac{\pi \cos\left(\frac{y}{h}q\right)\sin\left(\frac{s}{h}q\right)}{e^q \cosh q}$$

and

$$G_3(q,p) = \frac{\cos\left(\frac{y}{h}q\right)\sin\left(\frac{s}{h}q\right)}{q\left[\frac{1}{R^2}\cosh^2\left(\sqrt{\beta^2p^2 + q^2}\right) + \frac{p^2}{\beta^2p^2 + q^2}\sinh^2\sqrt{\beta^2p^2 + q^2}\right]}$$

In order to write the second integral in terms of R/β, the transformation $p = r/R$ (where R is a finite constant) is made. The machine calculations are made more accurate if the product $\cos\left(\frac{y}{h}q\right)\sin\left(\frac{s}{h}q\right)$ is written as

$$\cos\left(\frac{y}{h}q\right)\sin\left(\frac{s}{h}q\right) = \frac{1}{2}\left\{\sin\left[\left(\frac{s}{h} + \frac{y}{h}\right)q\right] + \sin\left[\left(\frac{s}{h} - \frac{y}{h}\right)q\right]\right\}$$

Finally, using the identity $\sinh^2 x = \cosh^2 x - 1$ and simplifying give equation (A3) in the form

$$\delta_3 = \frac{1}{2\pi^2}\frac{b/h}{s/h}\left[\int_0^\infty F_3'(q)dq - \int_0^\infty \int_0^\infty G_3'(q,r)dq\ dr\right] \tag{A4}$$

where

$$F_3'(q) = \frac{\pi}{2}\frac{\sin\left[\left(\frac{s}{h} + \frac{y}{h}\right)q\right] + \sin\left[\left(\frac{s}{h} - \frac{y}{h}\right)q\right]}{e^q \cosh q}$$

and

$$G_3'(q,r) = \frac{\left(\frac{\beta^2 r^2}{R^2} + q^2\right)\left\{\sin\left[\left(\frac{s}{h} + \frac{y}{h}\right)q\right] + \sin\left[\left(\frac{s}{h} - \frac{y}{h}\right)q\right]\right\}}{q\left\{\left[\left(\frac{\beta^2}{R^2} + 1\right)r^2 - q^2\right]\cosh^2\left(\sqrt{\frac{\beta^2 r^2}{R^2} + q^2}\right) - r^2\right\}}$$

The upwash interference factors due to the effect of horizontal boundaries on the interference velocity potential inside the test section due to vertical boundaries δ_4 (from eq. (C10) of ref. 1) and to the effect of horizontal boundaries on the interference velocity potential outside the test section due to horizontal boundaries δ_5 (from eq. (C12) of ref. 1) are given by

$$\delta_4 = \frac{1}{\pi^2}\frac{b/h}{s/h}\left[-\int_0^\infty\int_0^\infty G(q,r)G_4'(q,r)dq\ dr + \frac{2}{\pi R}\int_0^\infty\int_0^\infty\int_0^\infty H(q,r,p)H_4(q,r,p)dq\ dr\ dp\right] \tag{A5}$$

and

$$\delta_5 = \frac{1}{\pi^2}\frac{b/h}{s/h}\left[\int_0^\infty\int_0^\infty G(q,r)G_5'(q,r)dq\ dr + \frac{2}{\pi R}\int_0^\infty\int_0^\infty\int_0^\infty H(q,r,p)H_5(q,r,p)dq\ dr\ dp\right] \tag{A6}$$

where the symbols common to both equation (A5) and equation (A6), that is, $G(q,r)$ and $H(q,r,p)$ represent

$$G(q,r) = \frac{\sinh\left(\frac{s}{h}q\right)\cos\left(\frac{y}{h}r\right)\cos q}{\left(q^2 + r^2\right)e^{\frac{b}{h}q}\cosh r}$$

and

$$H(q,r,p) = \frac{q \sinh\left(\frac{s}{h}\sqrt{\beta^2 p^2 + q^2}\right)\cos\left(\frac{y}{h}r\right)}{\left(\beta^2 p^2 + q^2 + r^2\right)\left(\frac{p^2 \sinh^2\sqrt{\beta^2 p^2 + r^2}}{\beta^2 p^2 + r^2} + \frac{1}{R^2}\cosh^2\sqrt{\beta^2 p^2 + r^2}\right)e^{\left(\frac{b}{h}\sqrt{\beta^2 p^2 + q^2}\right)}}$$

The symbols $G_4'(q,r)$ and $H_4(q,r,p)$ in equation (A5) represent

$$G_4'(q,r) = \frac{q \sinh\left(\frac{b}{h}q\right)\cos\left(\frac{b}{h}r\right) + r \cosh\left(\frac{b}{h}q\right)\sin\left(\frac{b}{h}r\right)}{\sinh\left(\frac{b}{h}q\right)}$$

and

$$H_4(q,r,p) = H_{4,1}(q,r,p)\left[H_{4,2}(q,r,p)H_{4,3}(q,r,p) - H_{4,4}(q,r,p)H_{4,5}(q,r,p)\right]$$

where

$$H_{4,1}(q,r,p) = \frac{\sqrt{\beta^2 p^2 + q^2}\,\sinh\left(\frac{b}{h}\sqrt{\beta^2 p^2 + q^2}\right)\cos\left(\frac{b}{h}r\right) + r \cosh\left(\frac{b}{h}\sqrt{\beta^2 p^2 + q^2}\right)\sin\left(\frac{b}{h}r\right)}{\frac{\beta^2 p^2 + q^2}{R^2}\sinh^2\left(\frac{b}{h}\sqrt{\beta^2 p^2 + q^2}\right) + p^2 \cosh^2\left(\frac{b}{h}\sqrt{\beta^2 p^2 + q^2}\right)}$$

$$H_{4,2}(q,r,p) = \frac{\sinh\left(\frac{b}{h}\sqrt{\beta^2 p^2 + q^2}\right) + \cosh\left(\frac{b}{h}\sqrt{\beta^2 p^2 + q^2}\right)}{\sqrt{\beta^2 p^2 + q^2}}$$

$$H_{4,3}(q,r,p) = \frac{p^2 \sin q \sinh\sqrt{\beta^2 p^2 + r^2}}{\sqrt{\beta^2 p^2 + r^2}} + \frac{q}{R^2}\cos q \cosh\sqrt{\beta^2 p^2 + r^2}$$

$$H_{4,4}(q,r,p) = \frac{\sinh\left(\frac{b}{h}\sqrt{\beta^2 p^2 + q^2}\right)}{R^2} - \frac{p^2 \cosh\left(\frac{b}{h}\sqrt{\beta^2 p^2 + q^2}\right)}{\beta^2 p^2 + q^2}$$

and

$$H_{4,5}(q,r,p) = \sin q \cosh\sqrt{\beta^2 p^2 + r^2} - \frac{q \cos q \sinh\sqrt{\beta^2 p^2 + r^2}}{\sqrt{\beta^2 p^2 + r^2}}$$

In equation (A6), the symbols $G_5'(q,r)$ and $H_5(q,r,p)$ represent

$$G_5'(q,r) = q \cos\left(\frac{b}{h}r\right) - r \sin\left(\frac{b}{h}r\right)$$

and

$$H_5(q,r,p) = \frac{H_{4,5}(q,r,p)}{\beta^2p^2 + q^2}\left[\sqrt{\beta^2p^2 + q^2} \cos\left(\frac{b}{h}r\right) - r \sin\left(\frac{b}{h}r\right)\right]$$

Consider for a moment only the double-integral portions of equations (A5) and (A6). These represent the case of the completely closed tunnel. As with equation (A3), the calculation procedures are made more accurate by writing the product $\cos\left(\frac{y}{h}r\right)\sin\left(\frac{b}{h}r\right)$ and the product $\cos\left(\frac{y}{h}r\right)\cos\left(\frac{b}{h}r\right)$ as sines and cosines with arguments $\left(\frac{b}{h} + \frac{y}{h}\right)r$ and $\left(\frac{b}{h} - \frac{y}{h}\right)r$. The double integrals of equations (A5) and (A6) can thus be written

$$\delta_4 \text{ (double-integral portion)} = -\frac{1}{2\pi^2}\frac{b/h}{s/h}\int_0^\infty\int_0^\infty G'(q,r)G_4''(q,r)dq\,dr \tag{A7}$$

and

$$\delta_5 \text{ (double-integral portion)} = -\frac{1}{2\pi^2}\frac{b/h}{s/h}\int_0^\infty\int_0^\infty G'(q,r)G_5''(q,r)dq\,dr \tag{A8}$$

where

$$G'(q,r) = \frac{\cos q \sinh\left(\frac{s}{h}q\right)}{\left(q^2 + r^2\right)e^{\frac{b}{h}q}\cosh r}$$

$$G_4''(q,r) = \frac{K_4'(q,r) + K_4(q,r)}{\sinh\left(\frac{b}{h}q\right)}$$

$$K_4'(q,r) = q \sinh\left(\frac{b}{h}q\right)\cos\left[\left(\frac{b}{h} - \frac{y}{h}\right)r\right] + r \cosh\left(\frac{b}{h}q\right)\sin\left[\left(\frac{b}{h} - \frac{y}{h}\right)r\right]$$

$$K_4(q,r) = q \sinh\left(\frac{b}{h}q\right)\cos\left[\left(\frac{b}{h} + \frac{y}{h}\right)r\right] + r \cosh\left(\frac{b}{h}q\right)\sin\left[\left(\frac{b}{h} + \frac{y}{h}\right)r\right]$$

$$G_5''(q,r) = K_5'(q,r) - K_5(q,r)$$

$$K_5'(q,r) = q \cos\left[\left(\frac{b}{h} - \frac{y}{h}\right)r\right] - r \sin\left[\left(\frac{b}{h} - \frac{y}{h}\right)r\right]$$

$$K_5(q,r) = q \cos\left[\left(\frac{b}{h} + \frac{y}{h}\right)r\right] - r \sin\left[\left(\frac{b}{h} + \frac{y}{h}\right)r\right]$$

The triple-integral portions of equations (A5) and (A6) are formulated in terms of R/β by writing the dummy variable p as p'/R. If the obvious cancellations are made and the expression for $H_{4,2}(q,r,p)$ is simplified by writing it in terms of exponentials rather than as the sum of hyperbolic terms, triple integrals in terms of the dummy variables q, r, and p' are obtained. For convenience, the prime on the variable p' is dropped, and the triple-integral portions of equations (A5) and (A6) become

$$\delta_4 \text{ (triple-integral portion)} = \frac{2}{\pi^3} \frac{b/h}{s/h} \int_0^\infty \int_0^\infty \int_0^\infty H'(q,r,p) H_4'(q,r,p)\, dq\, dr\, dp \tag{A9}$$

and

$$\delta_5 \text{ (triple-integral portion)} = \frac{2}{\pi^3} \frac{b/h}{s/h} \int_0^\infty \int_0^\infty \int_0^\infty H'(q,r,p) H_5'(q,r,p)\, dq\, dr\, dp \tag{A10}$$

where

$$H'(q,r,p) = \frac{q \cos\left(\frac{y}{h} r\right) \sinh\left(\frac{s}{h}\sqrt{\frac{\beta^2 p^2}{R^2} + q^2}\right)}{e^{\left(\frac{b}{h}\sqrt{\frac{\beta^2 p^2}{R^2} + q^2}\right)} \left(\frac{\beta^2 p^2}{R^2} + q^2 + r^2\right) \left(\frac{p^2 \sinh^2 \sqrt{\frac{\beta^2 p^2}{R^2} + r^2}}{\frac{\beta^2 p^2}{R^2} + r^2} + \cosh^2 \sqrt{\frac{\beta^2 p^2}{R^2} + r^2}\right)}$$

$$H_4'(q,r,p) = H_{4,1}'(q,r,p)\left[H_{4,2}'(q,r,p) - H_{4,3}'(q,r,p) H_{4,4}'(q,r,p)\right]$$

$$H_{4,1}'(q,r,p) = \frac{\sqrt{\frac{\beta^2 p^2}{R^2} + q^2}\, \sinh\left(\frac{b}{h}\sqrt{\frac{\beta^2 p^2}{R^2} + q^2}\right) \cos\left(\frac{b}{h} r\right) + r \cosh\left(\frac{b}{h}\sqrt{\frac{\beta^2 p^2}{R^2} + q^2}\right) \sin\left(\frac{b}{h} r\right)}{\left(\frac{\beta^2 p^2}{R^2} + q^2\right) \sinh^2\left(\frac{b}{h}\sqrt{\frac{\beta^2 p^2}{R^2} + q^2}\right) + p^2 \cosh^2\left(\frac{b}{h}\sqrt{\frac{\beta^2 p^2}{R^2} + q^2}\right)}$$

$$H'_{4,2}(q,r,p) = \frac{e^{\left(\frac{b}{h}\sqrt{\frac{\beta^2p^2}{R^2}+q^2}\right)}}{\sqrt{\frac{\beta^2p^2}{R^2}+q^2}}\left(\frac{p^2 \sin q \sinh\sqrt{\frac{\beta^2p^2}{R^2}+r^2}}{\sqrt{\frac{\beta^2p^2}{R^2}+r^2}} + q \cos q \cosh\sqrt{\frac{\beta^2p^2}{R^2}+r^2}\right)$$

$$H'_{4,3}(q,r,p) = \sinh\left(\frac{b}{h}\sqrt{\frac{\beta^2p^2}{R^2}+q^2}\right) - \frac{p^2 \cosh\left(\frac{b}{h}\sqrt{\frac{\beta^2p^2}{R^2}+q^2}\right)}{\frac{\beta^2p^2}{R^2}+q^2}$$

$$H'_{4,4}(q,r,p) = \sin q \cosh\sqrt{\frac{\beta^2p^2}{R^2}+r^2} - \frac{q \cos q \sinh\sqrt{\frac{\beta^2p^2}{R^2}+r^2}}{\sqrt{\frac{\beta^2p^2}{R^2}+r^2}}$$

and

$$H'_5(q,r,p) = \frac{H'_{4,4}(q,r,p)}{\frac{\beta^2p^2}{R^2}+q^2}\left[\sqrt{\frac{\beta^2p^2}{R^2}+q^2}\cos\left(\frac{b}{h}r\right) - r \sin\left(\frac{b}{h}r\right)\right]$$

Investigation of the integrand of equation (A9) reveals a singularity at the simultaneous zero of all three integration variables. For small values of R/β this singularity can be ignored in the numerical integrations, but for moderate and large values it leads to difficulties in the calculation. In order to carry out the machine calculations for the entire range of R/β considered herein, it is necessary to break the triple integral of equation (A9) into several integrals, one of which is used to obtain an approximation for the integral near the simultaneous zero of the integration variables, and the others are used to calculate the integral over the remainder of the integration range. Thus in equation (A9), assume that the integration variables p, q, and r are all so close to zero that the transcendental functions in the integrand can be well approximated by the first-order terms in their series representations. After the indicated substitutions and simplifications are made, equation (A9) becomes

$$\delta_4 \text{ (triple-integral portion)}\Bigg|_{\substack{p\to 0\\ q\to 0\\ r\to 0}} = \frac{2}{\pi^3}\left(\frac{b}{h}\right)^2 \int_0^{\epsilon_1}\int_0^{\epsilon_2}\int_0^{\epsilon_3} \frac{q^2 dr\ dq\ dp}{\left(\frac{b}{h}\right)^2\left(\frac{\beta^2 p^2}{R^2} + q^2\right)^2 + p^2}$$

$$= \frac{2}{\pi^3}\epsilon_1 \int_0^{\epsilon_2}\int_0^{\epsilon_3} \frac{q^2 dq\ dp}{\left(\frac{\beta^2 p^2}{R^2} + q^2\right)^2 + \left(\frac{p}{b/h}\right)^2} \qquad \text{(A11)}$$

where the integration limits ϵ_1, ϵ_2, and ϵ_3 must be chosen small enough to make the approximation to equation (A9) valid. Equation (A11) becomes more amenable to integration by use of the transformation of variables

$$\frac{\beta p}{R} = \rho \sin \theta \qquad\qquad q = \rho \cos \theta$$

Whence,

$$\frac{\beta^2 p^2}{R^2} + q^2 = \rho^2$$

and the differential element is $\frac{R}{\beta}\rho\ d\rho\ d\theta$. As a result of applying this transformation and using the identity $\sin^2\theta + \cos^2\theta = 1$, equation (A11) becomes

$$\delta_4 \text{ (triple-integral portion)}\Bigg|_{\substack{\text{near}\\ \text{origin}}} = \frac{2\epsilon_1}{3}\frac{R}{\beta}\int_0^{\epsilon_2'} \rho\ d\rho \int_0^{\frac{\pi}{2}} \frac{\cos^2\theta\ d\theta}{a^2\sin^2\theta + \rho^2\cos^2\theta} \qquad \text{(A12)}$$

where $a^2 = \rho^2 + \left(\frac{R/\beta}{b/h}\right)^2$. In this expression, the integration limit ϵ_2' is the equivalent in the transformed coordinate system of ϵ_2 and ϵ_3 in the former system, but the integration region is now a quarter of a circular disk instead of a rectangle. Equation (A12) is a standard integral form in θ which can be integrated to give

$$\delta_4 \text{ (triple-integral portion)}\Bigg|_{\substack{\text{near}\\ \text{origin}}} = \frac{\epsilon_1}{\pi^2}\frac{R}{\beta}\int_0^{\epsilon_2'} \frac{d\rho}{\rho + \sqrt{\rho^2 + \left(\frac{R/\beta}{b/h}\right)^2}}$$

$$= \frac{\epsilon_1}{\pi^2}\frac{(b/h)^2}{R/\beta}\left[\int_0^{\epsilon_2'} \sqrt{\rho^2 + \left(\frac{R/\beta}{b/h}\right)^2}\, d\rho - \int_0^{\epsilon_2'} \rho\ d\rho\right]$$

This expression may then be integrated over ρ to yield

$$\delta_4 \text{ (triple-integral portion)}\Big|_{\substack{\text{near}\\ \text{origin}}} = \frac{\epsilon_1}{2\pi^2}\frac{(b/h)^2}{R/\beta}\left\{\epsilon_2'\sqrt{(\epsilon_2')^2 + \left(\frac{R/\beta}{b/h}\right)^2} + \left(\frac{R/\beta}{b/h}\right)^2 \ln\left[\epsilon_2' + \sqrt{(\epsilon_2')^2 + \left(\frac{R/\beta}{b/h}\right)^2}\right] - \left(\frac{R/\beta}{b/h}\right)^2 \ln\left(\frac{R/\beta}{b/h}\right) - (\epsilon_2')^2\right\} \tag{A13}$$

In order to perform the integration of equation (A9) over the remainder of its integration range, it is necessary first to apply the same coordinate transformation used to obtain equation (A12). The following equation results:

$$\delta_4 \text{ (triple-integral portion)} = \left[\text{Eq. (A13)}\right] + \frac{2}{\pi^3}\frac{b/h}{s/h}\left[\int_0^\infty dr \int_{\epsilon_2'}^\infty d\rho \int_0^{\frac{\pi}{2}} H_4''(r,\rho,\theta)d\theta + \int_{\epsilon_1}^\infty dr \int_0^{\epsilon_2'} d\rho \int_0^{\frac{\pi}{2}} H_4''(r,\rho,\theta)d\theta\right] \tag{A14}$$

where

$$H_4''(r,\rho,\theta) = H_{4,1}''(r,\rho,\theta)H_{4,2}''(r,\rho,\theta)\left[H_{4,3}''(r,\rho,\theta) + H_{4,4}''(\rho,\theta)H_{4,5}''(r,\rho,\theta)\right]$$

$$H_{4,1}''(r,\rho,\theta) = \frac{\cos\theta \sinh\left(\frac{s}{h}\rho\right)}{e^{\frac{b}{h}\rho}\left(\rho^2 + r^2\right)\left[\sinh^2\left(\frac{b}{h}\rho\right) + \left(\frac{R}{\beta}\right)^2 \sin^2\theta \cosh^2\left(\frac{b}{h}\rho\right)\right]}$$

$$H_{4,2}''(r,\rho,\theta) = \frac{L_{4,2}'(r,\rho) + L_{4,2}(r,\rho)}{\left(\frac{R}{\beta}\right)^2 \frac{\rho^2\sin^2\theta \sinh^2\sqrt{\rho^2\sin^2\theta + r^2}}{\rho^2\sin^2\theta + r^2} + \cosh^2\sqrt{\rho^2\sin^2\theta + r^2}}$$

$$L_{4,2}'(r,\rho) = \rho \sinh\left(\frac{b}{h}\rho\right)\cos\left[\left(\frac{b}{h} - \frac{y}{h}\right)r\right] + r \cosh\left(\frac{b}{h}\rho\right)\sin\left[\left(\frac{b}{h} - \frac{y}{h}\right)r\right]$$

$$L_{4,2}(r,\rho) = \rho \sinh\left(\frac{b}{h}\rho\right)\cos\left[\left(\frac{b}{h} + \frac{y}{h}\right)r\right] + r \cosh\left(\frac{b}{h}\rho\right)\sin\left[\left(\frac{b}{h} + \frac{y}{h}\right)r\right]$$

$$H''_{4,3}(r,\rho,\theta) = e^{\frac{b}{h}\rho}\left[\left(\frac{R}{\beta}\right)^2 \frac{\rho \sin^2\theta \sin(\rho \cos \theta)\sinh\sqrt{\rho^2\sin^2\theta + r^2}}{\sqrt{\rho^2\sin^2\theta + r^2}} + \cos \theta \cos(\rho \cos \theta)\cosh\sqrt{\rho^2\sin^2\theta + r^2}\right]$$

$$H''_{4,4}(\rho,\theta) = \sinh\left(\frac{b}{h}\rho\right) - \left(\frac{R}{\beta}\right)^2 \sin^2\theta \cosh\left(\frac{b}{h}\rho\right)$$

and

$$H''_{4,5}(r,\rho,\theta) = \frac{\rho \cos \theta \cos(\rho \cos \theta)\sinh \sqrt{\rho^2\sin^2\theta + r^2}}{\sqrt{\rho^2\sin^2\theta + r^2}} - \sin(\rho \cos \theta)\cosh\sqrt{\rho^2\sin^2\theta + r^2}$$

In the expression for $H''_{4,2}(r,\rho,\theta)$, the terms $L'_{4,2}(r,\rho)$ and $L_{4,2}(r,\rho)$ are the result of the product $\cos\left(\frac{y}{h}r\right)\sin\left(\frac{b}{h}r\right)$ and the product $\cos\left(\frac{y}{h}r\right)\cos\left(\frac{b}{h}r\right)$, similar to the analagous expressions of equations (A7) and (A8). In a like manner, the integrand of equation (A10) may be written as

$$H'(q,r,p)H'_5(q,r,p) = H_{5,1}(q,r,p)H_{5,2}(q,r,p)$$

where

$$H_{5,1}(q,r,p) = \frac{q \sinh\left(\frac{s}{h}\sqrt{\frac{\beta^2p^2}{R^2} + q^2}\right)}{e^{\left(\frac{b}{h}\sqrt{\frac{\beta^2p^2}{R^2}+q^2}\right)}\left(\frac{\beta^2p^2}{R^2} + q^2 + r^2\right)\left(\frac{p^2\sinh^2\sqrt{\frac{\beta^2p^2}{R^2} + r^2}}{\frac{\beta^2p^2}{R^2} + r^2} + \cosh^2\sqrt{\frac{\beta^2p^2}{R^2} + r^2}\right)}$$

$$H_{5,2}(q,r,p) = \frac{H'_{4,4}(q,r,p)}{\frac{\beta^2 p^2}{R^2} + q^2}\left[L'_5(q,r,p) + L_5(q,r,p)\right]$$

$$L'_5(q,r,p) = \sqrt{\frac{\beta^2 p^2}{R^2} + q^2}\cos\left[\left(\frac{b}{h} - \frac{y}{h}\right)r\right] - r\sin\left[\left(\frac{b}{h} - \frac{y}{h}\right)r\right]$$

and

$$L_5(q,r,p) = \sqrt{\frac{\beta^2 p^2}{R^2} + q^2}\cos\left[\left(\frac{b}{h} + \frac{y}{h}\right)r\right] - r\sin\left[\left(\frac{b}{h} + \frac{y}{h}\right)r\right]$$

APPENDIX B

FORTRAN PROGRAM FOR CALCULATING SPANWISE VARIATIONS IN WIND-TUNNEL-BOUNDARY LIFT-INTERFERENCE FACTORS FOR WINGS OF VARYING SPAN CENTER-MOUNTED IN RECTANGULAR PERFORATED TEST SECTIONS OF VARYING WIDTH-TO-HEIGHT RATIOS.

THIS PROGRAM WAS WRITTEN IN CDC FORTRAN, VERSION 2.1, TO RUN ON CDC 6000 SERIES COMPUTERS WITH THE SCOPE 3.0 OPERATING SYSTEM AND LIBRARY TAPE. MINOR MODIFICATIONS MAY BE REQUIRED PRIOR TO USE IN OTHER COMPUTERS. THIS PROGRAM HAS BEEN FOUND TO BE SATISFACTORY ON THE AFOREMENTIONED COMPUTERS WHICH CARRY THE EQUIVALENT OF APPROXIMATELY 15 DECIMAL DIGITS. COMPUTERS OF LESSER PRECISION MAY REQUIRE MODIFICATION TO DOUBLE PRECISION IN ORDER TO OBTAIN RESULTS OF EQUAL ACCURACY.

IN ORDER TO CONSERVE COMPUTER TIME AND SPACE, THIS PROGRAM IS WRITTEN AS A NUMBER OF SMALLER, INDEPENDENT PROGRAMS WHOSE PUNCHED-CARD OUTPUTS ARE COLLATED INTO FINAL FORM FOR PRODUCTION OF TABLES BY MEANS OF APPROPRIATE COMPUTER COLLATING PROGRAMS. FOR THE SAKE OF CONSISTENCY, TERMS COMMON TO ALL PROGRAMS HAVE BEEN ASSIGNED THE SAME NAMES IN ALL PROGRAMS. THESE TERMS FOLLOW

AP, AQ, AR = LOWER LIMITS OF INTEGRATION ON THE INTEGRATION INTERVALS OVER THE DUMMY VARIABLES P, Q, AND R.

BH = A ONE-DIMENSIONAL ARRAY IN WHICH ARE STORED THE VALUES OF TUNNEL SEMI-WIDTH TO SEMI-HEIGHT RATIO, B/H

BP, BQ, BR = UPPER LIMITS OF INTEGRATION ON THE INTEGRATION INTERVALS OVER THE DUMMY VARIABLES P, Q, AND R.

BS = THE RECIPROCAL OF SB.

BT = A ONE-DIMENSIONAL ARRAY IN WHICH ARE STORED THE VALUES OF BETA TO BE USED IN THE CALCULATIONS.

CNV = THE NUMBER WHICH DETERMINES INTEGRAL CONVERGENCE. IF THE EVALUATION OF THE INTEGRAL OVER A PARTICULAR INTERVAL IS LESS THAN CNV, CONVERGENCE IS ASSUMED AND THE INTEGRATION PROCESS TERMINATED.

FP, FQ, FR = ONE DIMENSIONAL ARRAYS IN WHICH ARE STORED THE VALUES OF INTEGRAND EVALUATIONS DURING THE INTEGRATION PROCESSES.

FUNCP, FUNCQ, FUNCR = NAMES OF SUBROUTINE SUBPROGRAMS WRITTEN TO EVALUATE THE INTEGRANDS IN THE DUMMY VARIABLES P, Q, AND R.

IB OR IBH = INDEX ON THE VARIABLE BH

INFINTP, INFINTQ, INFINTR = NAMES OF SUBROUTINES WHICH USE MGAUSP, MGAUSQ, AND MGAUSR, RESPECTIVELY, TO EVALUATE THE ≠INFINITE≠ INTEGRALS OVER THE DUMMY VARIABLES P, Q, AND R.

IP = INDEX ON VARIABLE RP.

APPENDIX B

IS OR ISH = INDEX ON THE VARIABLE SH

IY OR IYH = INDEX ON THE VARIABLE YH

JP, JQ, JR = THE MAXIMUM NUMBER OF INTEGRATION INTERVALS USED BEFORE NON-CONVERGENCE OF THE INTEGRALS IS ASSUMED.

MGAUSP, MGAUSQ, MGAUSR = NAMES OF SUBROUTINES FOR EVALUATING INTEGRALS BY THE GAUSS QUADRATURE METHOD OVER THE DUMMY VARIABLES P, Q, AND R, RESPECTIVELY.

NFP, NFQ, NFR = INTEGERS DEFINING THE NUMBER OF INTEGRANDS TO BE EVALUATED IN THE INTEGRATION SUBROUTINE CALL FOR ANY OF THE DUMMY VARIABLES P, Q, OR R.

NMY = NUMBER OF POINTS ALONG THE WING SPAN AT WHICH CALCULATIONS ARE TO BE MADE

NP, NQ, NR = INTEGERS DETERMINING THE NUMBER OF POINTS THE GAUSS QUADRATURE PROCEDURE USES PER INTEGRATION INTERVAL. THE NUMBER OF POINTS USED IS TEN TIMES THE VALUE OF NP, NQ, OR NR.

PI = 3.14159 26536

PNC, QNC, RNC = VARIABLES WHICH SET THE INTERVAL LENGTH FOR INTEGRATION OVER THE DUMMY VARIABLES P, Q, AND R.

P,Q,R = DUMMY VARIABLES OF INTEGRATION

PNT, QNT, RNT = ONE-DIMENSIONAL ARRAYS IN WHICH ARE STORED THE VALUES OF THE ANSWERS TO THE INTEGRATIONS OVER THE DUMMY VARIABLES P, Q, AND R.

RB = RATIO OF TUNNEL PERMEABILITY FACTOR TO BETA, R/BETA

RP = A ONE-DIMENSIONAL ARRAY IN WHICH ARE STORED THE VALUES OF THE PERMEABILITY FACTOR OF THE TUNNEL

SB = WING SEMI-SPAN TO TUNNEL SEMI-WIDTH RATIO, S/B

SH = A ONE-DIMENSIONAL ARRAY IN WHICH ARE STORED THE VALUES OF THE RATIO OF WING SEMI-SPAN TO TUNNEL SEMI-HEIGHT, S/H.

SMP, SMQ, SMR = ONE-DIMENSIONAL ARRAYS IN WHICH THE INTERMEDIATE ANSWERS TO THE INTEGRATION PROCESSES ARE STORED.

YH = A TWO-DIMENSIONAL ARRAY IN WHICH ARE STORED THE VALUES OF THE RATIO OF THE DISTANCE ALONG THE WING SEMI-SPAN TO THE TUNNEL SEMI-HEIGHT, Y/H.

YS = NORMALIZED DISTANCE ALONG WING SPAN, Y/S

APPENDIX B

FORTRAN PROGRAM FOR CALCULATING UPWASH INTERFERENCE FACTORS AT THE CENTER OF WINGS CENTER-MOUNTED IN RECTANGULAR COMPLETELY CLOSED (EQUATION (3) IN MAIN BODY OF REPORT) AND COMPLETELY OPEN (EQUATION (4) IN MAIN BODY OF REPORT) TEST SECTIONS. THESE EQUATIONS ARE INFINITE SUMMATIONS DERIVED BY THE METHOD OF IMAGES AS IN REFERENCE 2.

IN ADDITION TO THE COMMON VARIABLE NAMES ALREADY DEFINED, THE FOLLOWING NAMES ARE OF IMPORTANCE TO THIS PARTICULAR PROGRAM.

DLTC = CALCULATED UPWASH INTERFERENCE FACTOR FOR CLOSED TUNNEL

DLTO = CALCULATED UPWASH INTERFERENCE FACTOR FOR OPEN TUNNEL

I = INDEX ON VARIABLE SH

J = INDEX ON VARIABLE BH

K = INDEX ON SUMMATION. K IS THE SAME AS THE N OF EQUATIONS (3) AND (4).

KCO = THE VALUE OF K AT WHICH THE SUMMATION IS TRUNCATED.

ALL OTHER VARIABLE NAMES, EXCEPT AS NOTED, ARE USED MERELY AS BOOKKEEPING DEVICES.

NAMELIST INPUTS ARE BH, SH

```
      PROGRAMWT(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE1,TAPE2)
      DIMENSION BH(5),SB(2)$NAMELIST/INPT/BH,SB$READ(5,INPT)
      PI=2.*ASIN(1.)$PI2=PI/2.$DO1I=1,2$DO1J=1,5$PBH=PI2*BH(J)
      A1=PBH*SB(I)$T1=1./(4.*A1*SB(I))$T2=1./(4.*SB(I))$TC1=-T2/SINH(A1)
      TO1=-T2/TANH(A1)$A2=A3=0.$DO2K=1,25$AR1=PBH*(2.*K+SB(I))
      AR2=PBH*(2.*K-SB(I))$T4=1./SINH(AR2)-1./SINH(AR1)$A2=A2+T4
      T5=((-1.)**K)*(1./TANH(AR2)-1./TANH(AR1))$A3=A3+T5
```

T4 AND T5 REPRESENT THE SUMMATION TERMS IN EQUATIONS (3) AND (4), RESPECTIVELY, OF THE MAIN BODY OF THE REPORT. WHEN BOTH T4 AND T5 ARE LESS THAN 0.00001, THE SERIES ARE ASSUMED TO HAVE CONVERGED AND THE SUMMATION PROCESS IS TERMINATED.

```
      IF(ABS(T4).LT..00001.AND.ABS(T5).LT..00001)GOTO3$IF(K.EQ.25)GOTO3
    2 CONTINUE
    3 KCO=K$TC2=T2*A2$TO2=T2*A3$DLTC=T1+TC1+TC2$DLTO=T1+TO1+TC2
      WRITE(6,4)SB(I),BH(J),KCO,DLTC,DLTO
      WRITE(2,4)SB(I),BH(J),KCO,DLTC,DLTO
    4 FORMAT(//3X*S/B=*F6.2,3X*B/H=*F6.2,3X*SUMMATION INTEGER=*I3,//3X*D
     1ELTA,CENTER,CLOSED TUNNEL=*F8.4,5X*DELTA,CENTER,OPEN TUNNEL=*F8.4)
    1 CONTINUE$STOP$END
$INPT BH=.5,.75,1.,1.5,2.,SB=.3,.7,$
```

APPENDIX B

FORTRAN PROGRAM FOR EVALUATING THE CLOSED-TUNNEL PORTION OF EQUATION (A-2) OF APPENDIX A (THIS IS THE TERM CONTAINING THE EXPONENTIAL FACTOR). THE RESULTS GIVE UPWASH INTERFERENCE FACTORS FOR WINGS CENTER-MOUNTED BETWEEN INFINITE, VERTICAL, CLOSED BOUNDARIES.

IN ADDITION TO THE COMMON VARIABLE NAMES ALREADY DEFINED, THE FOLLOWING NAMES ARE OF IMPORTANCE TO THIS PARTICULAR PROGRAM.

DLTC2 = THE UPWASH INTERFERENCE FACTOR CALCULATED FOR THE CLOSED-TUNNEL PORTION OF EQUATION (A-2), WHICH REPRESENTS DELTA-SUB-2.

ALL OTHER VARIABLE NAMES, EXCEPT AS NOTED, ARE USED MERELY AS BOOKKEEPING DEVICES.

NAMELIST INPUTS ARE   BH

```
  PROGRAMWT(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE1,TAPE2,PUNCH)    (B 17)
  COMMONSH(2),ISH,YH(3,2),IYH,BH,IBH                                    (B 18)
  DIMENSIONFQ(1),SMQ(1),QNT(1),BH(5)$NAMELIST/INPT/BH$READ(5,INPT)      (B 19)
  NQ=2$NFQ=1$JQ=90$PI=3.141592636$QNC=PI/4.$CNV=1.E-07$NMY=3            (B 20)
```

THE FOLLOWING NEST OF DO-LOOPS INDEXES ON BH, SH, AND YH, CALCULATING THE VALUES OF SB, SH, YH, AND YS THEN USING THESE THROUGH THE SUBROUTINE SUBPROGRAMS INFINTQ, FUNCQ, AND MGAUSQ TO FIND THE INTEGRAL AND, FROM THAT, DLTC2. THE RESULTING DATA ARE PRINTED OUT AND PUNCHED ONTO DATA-PROCESSING CARDS FOR LATER COLLATION IN ANOTHER PROGRAM WITH THE DATA REPRESENTING THE PROGRESSIVELY MORE OPEN TUNNEL.

```
  DO1IBH=1,5$SH(1)=.3*BH(IBH)$SH(2)=.7*BH(IBH)$DO1ISH=1,2               (B 21)
  SB=SH(ISH)/BH(IBH)$BS=1./SB$WRITE(6,2)BH(IBH),SB                      (B 22)
  WRITE(2,2)BH(IBH),SB                                                  (B 23)
  DO1IYH=1,NMY$YH(IYH,ISH)=SH(ISH)*FLOAT(IYH-1)/FLOAT(NMY-1)            (B 24)
  YS=YH(IYH,ISH)/SH(ISH)$CALLINFINTQ(NQ,SMQ,FQ,NFQ,JQ,QNC,CNV,QNT)      (B 25)
  DLTC2=BS*QNT/(2.*PI)$WRITE(6,3)YS,DLTC2$WRITE(2,3)YS,DLTC2            (B 26)
2 FORMAT(1H ,///6X4HB/H=F7.3,10X4HS/B=F7.3,//5X3HY/S,6X*DELTA SUB C2    (B 27)
 1*//)                                                                  (B 28)
3 FORMAT(1H ,2XF6.2,3XF10.6)                                            (B 29)
  PUNCH4,BH(IBH),SB,YS,DLTC2                                            (B 30)
4 FORMAT(2(F7.3),F6.2,F10.6)                                            (B 31)
1 CONTINUE$STOP$END                                                     (B 32)
```

APPENDIX B

SUBROUTINE FUNCQ IS ONE WRITTEN TO EVALUATE THE INTEGRAND OF INTEREST OVER THE VARIABLE Q IN ACCORDANCE WITH THE INTEGRATION SUBROUTINE MGAUSQ. ITS CALLING ARGUMENTS ARE Q, THE VARIABLE OF INTEGRATION WHOSE VALUE IS SUPPLIED BY MGAUSQ, AND FQ, THE NAME OF AN ARRAY THAT WILL CONTAIN VALUES OF THE INTEGRANDS COMPUTED DURING THE INTEGRATION.

```
 SUBROUTINEFUNCQ(Q,FQ)$DIMENSIONFQ(1),BH(5)                          (B 33)
COMMONSH(2),ISH,YH(3,2),IYH,BH,IBH                                   (B 34)
SHQ=SH(ISH)*Q$YHQ=YH(IYH,ISH)*Q$BHQ=BH(IBH)*Q                        (B 35)
FQ=SINH(SHQ)*COSH(YHQ)/(EXP(BHQ)*SINH(BHQ))$RETURN$END               (B 36)
```

SUBROUTINE INFINTQ IS A GENERALIZED SUBROUTINE SUBPROGRAM WRITTEN TO EVALUATE ≠INFINITE≠ INTEGRALS BY MAKING USE OF SUB-ROUTINE MGAUSQ (WHICH EMPLOYS THE GAUSS QUADRATURE METHOD IN INTEGRAL EVALUATION) IN SUCCESSIVE STEPS BEGINNING AT THE LOWER LIMIT OF INTEGRATION. THE INTEGRATION INTERVAL FOR EACH SUCCESSIVE INTEGRATION STEP IS SET EXTERNALLY BY THE VARIABLE QINC IN THE CALLING ARGUMENTS OF INFINTQ. THE INTEGRAL VALUE IS INITIALIZED AT ZERO AND THE VALUE OF EACH SUCCESSIVE INTEGRATION STEP IS ADDED TO IT. THE INTEGER NFQ DETERMINES THE NUMBER OF INTEGRANDS TO BE EVALUATED, WITH ANSWERS STORED IN THE ARRAY QINT. WHEN THE SUMMED VALUES OF THE INTEGRALS OVER SOME PARTICULAR STEP ARE LESS THAN CONV, THEY ARE ALL ASSUMED TO HAVE CONVERGED AND THE INTEGRATION PROCESS IS TERMINATED. IF THE NUMBER OF INTEGRATION STEPS IS LARGER THAN THE INTEGER JQ, SET EXTERNALLY, THE INTEGRATION PROCESS IS TERMINATED AND AN ERROR MESSAGE THAT THE INTEGRAL IS NON-CONVERGENT WITH THE GIVEN UPPER LIMIT IS PRINTED. THE CALLING PROGRAM MUST DIMENSION THE ARRAYS SUMQ, FCFQ, AND QINT AT THE MAXIMUM NUMBER TO BE USED IN THAT PROGRAM.

```
   SUBROUTINE INFINTQ(NQ,SUMQ,FCFQ,NFQ,JQ,QINC,CONV,QINT)            (B 37)
   DIMENSION SUMQ(1),FCFQ(1),QINT(1) $DO1I=1,NFQ                     (B 38)
 1 QINT(I)=0.$AQ=0.$DO2IQ=1,JQ$IF(IQ-1)4,4,3                         (B 39)
 3 AQ=BQ                                                             (B 40)
 4 BQ=FLOAT(IQ)*QINC$CALLMGAUSQ(AQ,BQ,NQ,SUMQ,FOFQ,NFQ)              (B 41)
   QCONV=0.$DO5I=1,NFQ$QCONV=QCONV+ABS(SUMQ(I))                      (B 42)
 5 QINT(I)=QINT(I)+SUMQ(I)$IF(QCONV.LT.CONV)GOTO6$IF(IQ.EQ.JQ)GOTO7  (B 43)
   GOTO2                                                             (B 44)
 7 PRINT8$GOTO6                                                      (B 45)
 8 FORMAT(1H ,2X*INTEGRAL NONCONVERGENT WITH GIVEN UPPER LIMIT ON Q*) (B 46)
 2 CONTINUE                                                          (B 47)
 6 RETURN$END                                                        (B 48)
```

APPENDIX B

THE SUBROUTINE MGAUSQ EMPLOYS THE GAUSS QUADRATURE METHOD TO EVALUATE ≠NUMBER≠ NUMBER OF INTEGRANDS F(X)DX BETWEEN THE LIMITS A AND B. ANSWERS ARE STORED IN THE ARRAY SUM. FUNCQ IS THE NAME OF A SUBROUTINE SUBPROGRAM USED TO EVALUATE THE INTEGRANDS. THE NUMBER OF POINTS USED WITHIN THE INTEGRATION LIMITS IS TEN TIMES THE INTEGER N. THIS SUBROUTINE SUBPROGRAM IS A PRELIMINARY VERSION OF THE SUBROUTINE MGAUSS NOW ON THE LIBRARY TAPE OF THE CDC COMPUTER SYSTEM AT LANGLEY RESEARCH CENTER. A MORE COMPLETE DISCUSSION OF IT THAN GIVEN HERE IS GIVEN IS SECTION D 1.1, VOLUME I, OF THE LANGLEY RESEARCH CENTER COMPUTER PROGRAMMING MANUAL.

```
     SUBROUTINE MGAUSQ(A,B,N,SUM,FOFX,NUMBER)                             (B 49)
    DIMENSION U(5),R(5),SUM(1),FOFX(1)$DO1LL=1,NUMBER                     (B 50)
  1 SUM(LL)=0.0                                                           (B 51)
    IF(A.EQ.B)RETURN$U(1)=.425562830509184$U(2)=.283302302985376          (B 52)
    U(3)=.160295215550488$U(4)=.067468316655508$U(5)=.013046735741414     (B 53)
    R(1)=.147762112357376$R(2)=.134633359654998$R(3)=.109543181257991     (B 54)
    R(4)=.074725674575290$R(5)=.033335672154344$FINE=N                    (B 55)
    DELTA=FINE/(B-A)$DO3K=1,N$XI=K-1$FINE=A+XI/DELTA$DO2II=1,5            (B 56)
    UU=U(II)/DELTA+FINE$CALLFUNCQ(UU,FOFX)$DO2JOYBOY=1,NUMBER             (B 57)
  2 SUM(JOYBOY)=R(II)*FOFX(JOYBOY)+ SUM(JOYBOY)$DO3JJ=1,5                 (B 58)
    UU=(1.0-U(JJ))/DELTA+FINE$CALLFUNCQ(UU,FOFX)$DO3NN=1,NUMBER           (B 59)
  3 SUM(NN)=R(JJ)*FOFX(NN)+SUM(NN)$DO7IJK=1,NUMBER                        (B 60)
  7 SUM(IJK)=SUM(IJK)/DELTA $RETURN$END                                   (B 61)

$INPT BH=.5,.75,1.,1.5,2.,$                                               (B 62)
```

APPENDIX B

FORTRAN PROGRAM FOR EVALUATING THE CLOSED-TUNNEL PORTION OF EQUATION (A-4) OF APPENDIX A (THIS IS THE TERM CONTAINING THE SINGLE INTEGRAL). THE RESULTS GIVE UPWASH INTERFERENCE FACTORS FOR WINGS CENTER-MOUNTED BETWEEN INFINITE, HORIZONTAL, CLOSED BOUNDARIES.

IN ADDITION TO THE COMMON VARIABLE NAMES ALREADY DEFINED, THE FOLLOWING NAMES ARE OF IMPORTANCE TO THIS PARTICULAR PROGRAM.

ARGYS = THE VARIABLE MULTIPLIED ONTO THE VARIABLE OF INTEGRATION TO MAKE UP THE ARGUMENT OF THE SINE TERM OF THE INTEGRAND.

D1 = THE VALUE OF THE INTEGRAL RESULTING FROM USE OF A POSITIVE SIGN IN THE VARIABLE ARGYS.

D2 = THE VALUE OF THE INTEGRAL RESULTING FROM USE OF A NEGATIVE SIGN IN THE VARIABLE ARGYS.

DLTC3 = THE UPWASH INTERFERENCE FACTOR CALCULATED FOR THE CLOSED-TUNNEL PORTION OF EQUATION (A-4), WHICH REPRESENTS DELTA-SUB-3.

ALL OTHER VARIABLE NAMES, EXCEPT AS NOTED, ARE USED MERELY AS BOOKKEEPING DEVICES.

NAMELIST INPUTS ARE BH

```
PROGRAMWT(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE1,TAPE2,PUNCH)   (B 63)
DIMENSIONFQ(1),SMQ(1),QNT(1),SH(2),YH(3,2),BH(5)                     (B 64)
COMMONARGYS$NAMELIST/INPT/BH$READ(5,INPT)                            (B 65)
NQ=5$NFQ=1$JQ=50$PI=3.1415926536$CNV=1.E-07$NMY=3                    (B 66)
```

IN ADDITION TO THE OPERATIONS PERFORMED BY THE NESTED DO-LOOPS OF THE PRECEDING PROGRAM, THOSE OF THIS PROGRAM PERFORM TWO SEPARATE INTEGRATIONS. IN THE FIRST, THE VARIABLE MULTIPLYING THE INTEGRATION VARIABLE IN THE ARGUMENT OF THE SINE TERM OF THE INTEGRAND HAS A POSITIVE SIGN. IN THE SECOND, IT HAS A NEGATIVE SIGN. FOR EACH INTEGRATION, QNC -- THE VARIABLE SETTING THE INTEGRATION INTERVAL -- IS A FUNCTION OF ARGYS. THIS PROCEDURE RESTRICTS THE INTEGRATION LIMITS ON ANY PARTICULAR INTEGRATION INTERVAL SUCH THAT THE ARGUMENT OF THE SINE TERM IN THE INTEGRAND IS SOME MULTIPLE OF PI AT THE LIMITS.

```
  DO1IBH=1,5$SH(1)=.3*BH(IBH)$SH(2)=.7*BH(IBH)$DO1ISH=1,2              (B 67)
  SB=SH(ISH)/BH(IBH)$BS=1./SB$WRITE(6,2)BH(IBH),SB                      (B 68)
  WRITE(2,2)BH(IBH),SB                                                  (B 69)
2 FORMAT(1H ,///5X4HB/H=F7.3,10X4HS/B=F7.3,//5X5HY/S,8X2HD1,12X2HD2,   (B 70)
 18X*DELTA SUB C3*//)                                                   (B 71)
  DO1IYH=1,NMY$YH(IYH,ISH)=SH(ISH)*FLOAT(IYH-1)/FLOAT(NMY-1)            (B 72)
  ARGYS=YH(IYH,ISH)+SH(ISH)$YS=YH(IYH,ISH)/SH(ISH)                      (B 73)
  QNC=PI/ARGYS$CALLINFINTQ(NQ,SMQ,FQ,NFQ,JQ,QNC,CNV,QNT)$D1=QNT         (B 74)
```

IF IYH = NMY, THE VARIABLE ARGYS = 0 AND THE VALUE OF THE INTEGRAL IS ZERO.

```
      IF(IYH.EQ.NMY)GOTO6                                                  (B 75)
      ARGYS=YH(IYH,ISH)-SH(ISH)$QNC=PI/ABS(ARGYS)$YS=YH(IYH,ISH)/SH(ISH)   (B 76)
      CALLINFINTQ(NQ,SMQ,FQ,NFQ,JQ,QNC,CNV,QNT)$D2=QNT$GOTO7               (B 77)
    6 D2=0.                                                                (B 78)
    7 DLTC3=BS*(D1-D2)/(4.*PI)$WRITE(6,3)YS,D1,D2,DLTC3                    (B 79)
      WRITE(2,3)YS,D1,D2,DLTC3                                             (B 80)
    3 FORMAT(1H ,2XF6.2,3(4XF10.6))                                        (B 81)
      PUNCH4,BH(IBH),SB,YS,DLTC3                                           (B 82)
    4 FORMAT(2(F7.3),F6.2,F10.6)                                           (B 83)
    1 CONTINUE$STOP$END                                                    (B 84)
```

SUBROUTINE FUNCQ IS ONE WRITTEN TO EVALUATE THE INTEGRAND OF INTEREST OVER THE VARIABLE Q IN ACCORDANCE WITH THE INTEGRATION SUBROUTINE MGAUSQ. REFER TO DISCUSSION IN THE PRECEDING PROGRAM.

```
       SUBROUTINE FUNCQ(Q,FQ)$COMMON ARGYS$ARG=ARGYS*Q                     (B 85)
      FQ=SIN(ARG)/(EXP(Q)*COSH(Q))$RETURN$END                              (B 86)

$INPT BH=.5,.75,1.,1.5,2.$                                                (B 112)
```

THIS PROGRAM MAKES USE OF THE SUBROUTINE SUBPROGRAMS INFINTQ AND MGAUSQ AS DEFINED AND DISCUSSED IN THE PRECEDING PROGRAM.

APPENDIX B

FORTRAN PROGRAM FOR EVALUATING EQUATION (A-7) -- WHICH REPRESENTS THE UPWASH INTERFERENCE FACTORS DUE TO THE EFFECT OF HORIZONTAL CLOSED BOUNDARIES ON THE INTERFERENCE VELOCITY POTENTIAL INSIDE THE TEST SECTION DUE TO VERTICAL CLOSED BOUNDARIES -- OF APPENDIX A AND EQUATION (A-8) -- WHICH REPRESENTS THE EFFECT OF HORIZONTAL CLOSED BOUNDARIES ON THE INTERFERENCE VELOCITY POTENTIAL OUTSIDE THE TEST SECTION DUE TO THE HORIZONTAL CLOSED BOUNDARIES. THIS PROGRAM DIFFERS FROM THE PRECEDING ONES IN THAT DOUBLE INFINITE INTEGRALS IN TWO VARIABLES ARE CALCULATED RATHER THAN THE SINGLE INFINITE INTEGRAL IN ONE VARIABLE CALCULATED IN THE PRECEDING PROGRAMS.

IN ADDITION TO THE COMMON VARIABLE NAMES ALREADY DEFINED, THE FOLLOWING NAMES ARE OF IMPORTANCE TO THIS PARTICULAR PROGRAM.

A1 = A ONE-DIMENSIONAL ARRAY IN WHICH ARE STORED THE VALUES OF THE INTEGRALS RESULTING FROM USE OF A POSITIVE SIGN IN THE VARIABLE ≠BY≠.

A2 = A ONE-DIMENSIONAL ARRAY IN WHICH ARE STORED THE VALUES OF THE INTEGRALS RESULTING FROM USE OF A NEGATIVE SIGN IN THE VARIABLE ≠BY≠.

BY = A VARIABLE WHICH SERVES THE SAME FUNCTION AS THE VARIABLE ARGYS IN THE PRECEDING PROGRAM.

DLTC4 = THE UPWASH INTERFERENCE FACTOR CALCULATED FOR EQUATION (A-7).

DLTC5 = THE UPWASH INTERFERENCE FACTOR CALCULATED FOR EQUATION (A-8).

ALL OTHER VARIABLE NAMES, EXCEPT AS NOTED, ARE USED MERELY AS BOOKKEEPING DEVICES.

NAMELIST INPUTS ARE BH

```
      PROGRAMWT(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE1,TAPE2,PUNCH)
      COMMONSH(2),IS,YH(3,2),IY,BH,IB,Q,BY,PI
      DIMENSION A1(2),A2(2)
      DIMENSIONFQ(2),SMQ(2),QNT(2),BH(5)$NAMELIST/INPT/BH$READ(5,INPT)
      NQ=3$NFQ=2$JQ=50$PI=3.1415926536$CNV=1.E-07$NMY=3
      DO1IB=1,5$SH(1)=.3*BH(IB)$SH(2)=.7*BH(IB)$DO1IS=1,2
      SB=SH(IS)/BH(IB)$BS=1./SB$WRITE(6,2)BH(IB),SB
      WRITE(2,2)BH(IB),SB
    2 FORMAT(1H ,///6X4HB/H=F7.3,10X4HS/B=F7.3,//5X3HY/S,7X*DELTA SUB C4
     1*,2X*DELTA SUB C5*//)
      DO1IY=1,NMY$YH(IY,IS)=SH(IS)*FLOAT(IY-1)/FLOAT(NMY-1)
      BY=BH(IB)+YH(IY,IS)$QNC=PI
      YS=YH(IY,IS)/SH(IS)$CALLINFINTQ(NQ,SMQ,FQ,NFQ,JQ,QNC,CNV,QNT)
      A1(1)=QNT(1)$A1(2)=QNT(2)$BY=BH(IB)-YH(IY,IS)
      CALLINFINTQ(NQ,SMQ,FQ,NFQ,JQ,QNC,CNV,QNT)$A2(1)=QNT(1)
      A2(2)=QNT(2)$DLTC4=-BS*(A1(1)+A2(1))/(2.*PI*PI)
      DLTC5=BS*(A1(2)+A2(2))/(2.*PI*PI)$WRITE(6,3)YS,DLTC4,DLTC5
      WRITE(2,3)YS,DLTC4,DLTC5
    3 FORMAT(1H ,2XF6.2,2(4XF10.6))
      PUNCH4,BH(IB),SB,YS,DLTC4,DLTC5
    4 FORMAT(2(F7.3),F6.2,2(F10.6))
    1 CONTINUE$STOP$END
```

APPENDIX B

```
     IN ADDITION TO PERFORMING THE FUNCTIONS PERFORMED BY SUBROUTINES
  OF THE SAME NAME IN PRECEDING PROGRAMS, THE SUBROUTINE FUNCQ IN THIS
  PROGRAM MAKES USE OF THE SUBROUTINES INFINTR AND MGAUSR IN ORDER
  TO PERFORM THE SECOND INTEGRATION OVER THE VARIABLE R REQUIRED BY
  EQUATIONS (A-7) AND (A-8).

 SUBROUTINE FUNCQ(Q,FQ)$DIMENSIONFQ(2),SMR(2),FR(2),RNT(2),BH(5)    (B 135)
COMMONSH(2),IS,YH(3,2),IY,BH,IB,S,BY,PI$S=Q$NR=2$NFR=2$JR=50        (B 136)

  IN THIS PROGRAM, THE INTEGRATION INTERVAL RNC IS A FUNCTION OF
  THE VARIABLE ≠BY≠ ANALOGOUSLY TO AND FOR THE SAME REASONS THAT THE
  INTEGRATION INTERVAL QNC IS A FUNCTION OF THE VARIABLE ARGYS IN THE
  PRECEDING PROGRAM FOR DLTC3.

RNC=PI/ABS(BY)$CNV=1.E-07$CALLINFINTR(NR,SMR,FR,NFR,JR,RNC,CNV,FQ)  (B 137)
RETURN$END                                                          (B 138)

     SUBROUTINE FUNCR IS ONE WRITTEN TO EVALUATE THE INTEGRAND OF
  INTEREST OVER THE VARIABLES Q AND R IN ACCORDANCE WITH THE INTEGRATION
  SUBROUTINES INFINTQ, INFINTR, MGAUSQ, AND MGAUSR.

 SUBROUTINE FUNCR(R,FR)$DIMENSIONFR(2),BH(5)                        (B 139)
COMMONSH(2),IS,YH(3,2),IY,BH,IB,Q,BY,PI$SHQ=SH(IS)*Q$BHQ=BH(IB)*Q   (B 140)
ARG1=COS(Q)*SINH(SHQ)/(EXP(BHQ)*(Q*Q+R*R)*COSH(R))$BYR=BY*R         (B 141)
ARG2=(Q*SINH(BHQ)*COS(BYR)+R*COSH(BHQ)*SIN(BYR))/SINH(BHQ)          (B 142)
ARG3=Q*COS(BYR)-R*SIN(BYR)$FR(1)=ARG1*ARG2$FR(2)=ARG1*ARG3          (B 143)
RETURN$END                                                          (B 144)
```

APPENDIX B

THE SUBROUTINE SUBPROGRAMS INFINTR AND MGAUSR IN THIS PROGRAM ARE NECESSARY TO ALLOW INTEGRATIONS OVER TWO VARIABLES RATHER THAN THE ONE VARIABLE OF PRECEDING PROGRAMS. EXCEPTING FOR THE SUBROUTINE NAMES AND WHATEVER VARIABLE NAME-CHANGES ARE NECESSARY TO ALLOW THE CALCULATIONS TO PROCEED WITHOUT CONFUSION, THEY ARE IDENTICAL WITH THE SUBROUTINES INFINTQ AND MGAUSQ AS DISCUSSED IN A PRECEDING PROGRAM.

```
   SUBROUTINE INFINTR(NQ,SUMQ,FOFR,NFQ,JQ,QINC,CONV,QINT)           (B 145)
  DIMENSION SUMQ(1),FOFR(1),QINT(1) $DO1I=1,NFQ                     (B 146)
1 QINT(I)=0.$AQ=0.$DO2IQ=1,JQ$IF(IQ-1)4,4,3                         (B 147)
3 AQ=BQ                                                             (B 148)
4 BQ=FLOAT(IQ)*QINC$CALLMGAUSR(AQ,BQ,NQ,SUMQ,FOFR,NFQ)              (B 149)
  QCONV=0.$DO5I=1,NFQ$QCONV=QCONV+ABS(SUMQ(I))                      (B 150)
5 QINT(I)=QINT(I)+SUMQ(I)$IF(QCONV.LT.CONV)GOTO6$IF(IQ.EQ.JQ)GOTO7  (B 151)
  GOTO2                                                             (B 152)
7 WRITE(6,8)$WRITE(2,8)$GOTO6                                       (B 153)
8 FORMAT(1H ,2X*INTEGRAL NONCONVERGENT WITH GIVEN UPPER LIMIT ON R*) (B 154)
2 CONTINUE                                                          (B 155)
6 RETURN$END                                                        (B 156)


   SUBROUTINE MGAUSR(A,B,N,SUM,FOFX,NUMBER)                         (B 182)
  DIMENSION U(5),R(5),SUM(1),FOFX(1)$DO1LL=1,NUMBER                 (B 183)
1 SUM(LL)=0.0                                                       (B 184)
  IF(A.EQ.B)RETURN$U(1)=.425562830509184$U(2)=.283302302985376      (B 185)
  U(3)=.160295215850488$U(4)=.067468316655508$U(5)=.013046735741414 (B 186)
  R(1)=.147762112357376$R(2)=.134633359654998$R(3)=.109543181257991 (B 187)
  R(4)=.074725674575290$R(5)=.033335672154344$FINE=N                (B 188)
  DELTA=FINE/(B-A)$DO3K=1,N$XI=K-1$FINE=A+XI/DELTA$DO2II=1,5        (B 189)
  UU=U(II)/DELTA+FINE$CALLFUNCR(UU,FOFX)$DO2JOYBOY=1,NUMBER         (B 190)
2 SUM(JOYBOY)=R(II)*FOFX(JOYBOY)+ SUM(JOYBOY)$DO3JJ=1,5             (B 191)
  UU=(1.0-U(JJ))/DELTA+FINE$CALLFUNCR(UU,FOFX)$DO3NN=1,NUMBER       (B 192)
3 SUM(NN)=R(JJ)*FOFX(NN)+SUM(NN)$DO7IJK=1,NUMBER                    (B 193)
7 SUM(IJK)=SUM(IJK)/DELTA $RETURN$END                               (B 194)

$INPT BH=.5,.75,1.,1.5,2.,$                                         (B 195)
```

THIS PROGRAM MAKES USE OF THE SUBROUTINE SUBPROGRAMS INFINTQ AND MGAUSQ AS DEFINED AND DISCUSSED IN A PRECEDING PROGRAM.

APPENDIX B

FORTRAN PROGRAM FOR COLLATING DATA. THE PUNCHED-CARD OUTPUT OF THE THREE PRECEDING PROGRAMS -- WHICH REPRESENTS UPWASH INTERFERENCE FACTORS FOR WINGS CENTER-MOUNTED IN CLOSED RECTANGULAR WIND TUNNELS AS DEFINED IN THOSE PROGRAMS AND APPENDIX A -- IS THE INPUT TO THIS PROGRAM. THE DATA AS READ INTO THE PROGRAM ARE PRINTED-OUT, THEN COLLATED AND RE-PRINTED AS A CHECK. THE COLLATED DATA ARE ALSO OUTPUT ON PUNCHED DATA-PROCESSING CARDS FOR LATER COLLATION WITH THE DATA REPRESENTING UPWASH INTERFERENCE FACTORS FOR WINGS CENTER-MOUNTED IN PROGRESSIVELY MORE OPEN RECTANGULAR PERFORATED WIND TUNNELS.

IN ADDITION TO THE COMMON VARIABLE NAMES ALREADY DEFINED, THE FOLLOWING NAMES ARE OF IMPORTANCE TO THIS PARTICULAR PROGRAM.

D2 = DLTC2 OF A PRECEDING PROGRAM.

D3 = DLTC3 OF A PRECEDING PROGRAM.

D4 = DLTC4 OF A PRECEDING PROGRAM.

D5 = DLTC5 OF A PRECEDING PROGRAM.

ALL OTHER VARIABLE NAMES, EXCEPT AS NOTED, ARE USED MERELY AS BOOKKEEPING DEVICES.

```
      PROGRAMWT(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE1,TAPE2,PUNCH)
      DIMENSIONBH(30,3),SB(30,3),YS(30,3),D2(30),D3(30),D4(30),D5(30)
      READ(5,1)(BH(I,1),SB(I,1),YS(I,1),D2(I),I=1,30)
      READ(5,1)(BH(I,2),SB(I,2),YS(I,2),D3(I),I=1,30)
    1 FORMAT(2(F7.3),F6.2,F10.6)
      READ(5,2)(BH(I,3),SB(I,3),YS(I,3),D4(I),D5(I),I=1,30)
    2 FORMAT(2(F7.3),F6.2,2(F10.6))
      WRITE(6,3)(BH(I,1),SB(I,1),YS(I,1),D2(I),I=1,30)
      WRITE(6,5)(BH(I,2),SB(I,2),YS(I,2),D3(I),I=1,30)
      WRITE(6,4)(BH(I,3),SB(I,3),YS(I,3),D4(I),D5(I),I=1,30)
      WRITE(6,6)(SB(I,1),BH(I,1),YS(I,1),D2(I),D3(I),D4(I),D5(I),I=1,30)
      WRITE(2,6)(SB(I,1),BH(I,1),YS(I,1),D2(I),D3(I),D4(I),D5(I),I=1,30)
    3 FORMAT(1H ,//2X*S/B*4X*B/H*3X*Y/S*2X*DELTA SUB C2*//(2(F7.3),F6.2,
     1F12.6))
    4 FORMAT(1H ,//2X*S/B*4X*B/H*3X*Y/S*2X*DELTA SUB C4*4X*DELTA SUB C5*
     1//(2(F7.3),F6.2,F12.6,4XF12.6))
    5 FORMAT(1H ,//2X*S/B*4X*B/H*3X*Y/S*2X*DELTA SUB C3*//(2(F7.3),F6.2,
     1F12.6))
    6 FORMAT(1H ,//2X*S/B*4X*B/H*3X*Y/S*4X*DELTA SUB C2*4X*DELTA SUB C3*
     14X*DELTA SUB C4*4X*DELTA SUB C5*//(2(F7.3),F6.2,4(4XF12.6)))
      IA=-2$DO10J=1,2$IA=IA+3$M=IA-6$DO10K=1,5$M=M+6$N=M+2
      WRITE(6,7)(SB(I,1),BH(I,1),YS(I,1),D2(I),D3(I),D4(I),D5(I),I=M,N)
      WRITE(2,7)(SB(I,1),BH(I,1),YS(I,1),D2(I),D3(I),D4(I),D5(I),I=M,N)
    7 FORMAT(2(F7.3),F6.2,4(2XF12.6))
      PUNCH8,(SB(I,1),BH(I,1),YS(I,1),D2(I),D3(I),D4(I),D5(I),I=M,N)
    8 FORMAT(2(F7.3),F6.2,4(F12.6))
   10 CONTINUE$STOP$END
```

FORTRAN PROGRAM FOR EVALUATING THE PROGRESSIVELY-MORE-OPEN-TUNNEL PORTION OF EQUATION (A-2) OF APPENDIX A (THIS IS THE TERM CONTAINING THE HYPERBOLIC SECANT IN THE INTEGRAND). THE RESULTS GIVE UPWASH INTERFERENCE FACTORS FOR WINGS CENTER-MOUNTED BETWEEN INFINITE, VERTICAL, PERFORATED BOUNDARIES.

IN ADDITION TO THE COMMON VARIABLE NAMES ALREADY DEFINED, THE FOLLOWING NAMES ARE OF IMPORTANCE TO THIS PARTICULAR PROGRAM.

DLTO2 = THE UPWASH INTERFERENCE FACTOR CALCULATED FOR THE PROGRESSIVELY-MORE-OPEN-PERFORATED-TUNNEL PORTION OF EQUATION (A-2).

ALL OTHER VARIABLE NAMES, EXCEPT AS NOTED, ARE USED MERELY AS BOOKKEEPING DEVICES.

NAMELIST INPUTS ARE BH, BT, RP

```
      PROGRAMWT(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE1,TAPE2,PUNCH)  (B 223)
      COMMONSH(2),IS,YH(3,2),IY,BH,IB,PI,RB                               (B 224)
      DIMENSIONFQ(1),SMQ(1),QNT(1),BH(5),BT(5),RP(4)                      (B 225)
      NAMELIST/INPT/BH,BT,RP$READ(5,INPT)                                 (B 226)
      NQ=4$NFQ=1$JQ=50$PI=3.14159265 36$CNV=1.E-07$NMY=3                  (B 227)
      DO1IS=1,2$DO1IB=1,5   $SH(1)=.3*BH(IB)$SH(2)=.7*BH(IB)$DO1IP=1,4    (B 228)
      DO1IT=1,5   $RB=RP(IP)/BT(IT)                                       (B 229)
```

IN THIS PROGRAM, THE INTEGRATION INTERVAL QNC IS MADE A FUNCTION OF THE VARIABLE RB AND THE INDEXING INTEGER IP IN ORDER TO GIVE THE SAME NUMBER OF INTEGRATION POINTS PER UNIT LENGTH OF THE INTEGRATION VARIABLE Q IN THE ARGUMENTS OF THE TRANSCENDENTAL FUNCTIONS IN THE INTEGRAND. THIS ALSO PRODUCES APPROXIMATELY THE SAME AMOUNT OF COMPUTER PROCESSING TIME FOR THE EVALUATION OF EACH TEST CASE.

```
      QNC=RB/FLOAT(IP)$SB=SH(IS)/BH(IB)$BS=1./SB                          (B 230)
      WRITE(2,2)BH(IB),SB,RB$WRITE(6,2)BH(IB),SB,RB                       (B 231)
    2 FORMAT(1H ,///6X4HB/H=F7.3,10X4HS/B=F7.3,10X*R/BETA=*F7.3,//5X3HY/  (B 232)
     1S,7X*DELTA SUB U2*//)                                               (B 233)
      DO1IY=1,NMY$YH(IY,IS)=SH(IS)*FLOAT(IY-1)/FLOAT(NMY-1)               (B 234)
      YS=YH(IY,IS)/SH(IS)$CALLINFINTQ(NQ,SMQ,FQ,NFQ,JQ,QNC,CNV,QNT)       (B 235)
      DLTO2=BS*QNT/(2.*PI)$WRITE(6,3)YS,DLTO2$WRITE(2,3)YS,DLTO2          (B 236)
      PUNCH4,SB,BH(IB),RB,YS,DLTO2                                        (B 237)
    4 FORMAT(3(F7.3),F6.2,F10.6)                                          (B 238)
    3 FORMAT(4XF6.2,6XF10.6)                                              (B 239)
    1 CONTINUE$STOP$END                                                   (B 240)
```

SUBROUTINE FUNCQ IS ONE WRITTEN TO EVALUATE THE INTEGRAND OF INTEREST OVER THE VARIABLE Q IN ACCORDANCE WITH THE INTEGRATION SUBROUTINE MGAUSQ. REFER TO DISCUSSION IN A PRECEDING PROGRAM.

```
 SUBROUTINE FUNCQ(Q,FQ)$DIMENSIONFQ(1),BH(5)                          (B 241)
COMMONSH(2),IS,YH(3,2),IY,BH,IB,FI,RB                                 (B 242)
SQ=SH(IS)*Q$YQ=YH(IY,IS)*Q$BQ=BH(IB)*Q$BR=1./RB                       (B 243)
A1=SINH(SQ)*COSH(YQ)/(SINH(BQ)*COSH(BQ))                              (B 244)
A2=SQRT(BR*BR*TANH(BQ)*TANH(BQ)+1.)                                   (B 245)
FQ=A1*(BR*TANH(BQ)-A2)$RETURN$END                                     (B 246)

$INPT BH=.5,.75,1.,1.5,2.,BT=1.,.8,.6,.45,.3,RP=.1,.45,2.,7.5,$        (B 272)
```

THIS PROGRAM MAKES USE OF THE SUBROUTINE SUBPROGRAMS INFINTQ AND MGAUSQ AS DEFINED AND DISCUSSED IN A PRECEDING PROGRAM.

APPENDIX B

FORTRAN PROGRAM FOR EVALUATING THE PROGRESSIVELY-MORE-OPEN-TUNNEL PORTION OF EQUATION (A-4) OF APPENDIX A (THIS IS THE DOUBLE-INTEGRAL PORTION OF THE EQUATION). THE RESULTS GIVE UPWASH INTERFERENCE FACTORS FOR WINGS CENTER-MOUNTED BETWEEN INFINITE, HORIZONTAL, PERFORATED BOUNDARIES.

IN ADDITION TO THE COMMON VARIABLE NAMES ALREADY DEFINED, THE FOLLOWING NAMES ARE OF IMPORTANCE TO THIS PARTICULAR PROGRAM.

AYS = A VARIABLE WHICH SERVES THE SAME FUNCTION AS THE VARIABLE ARGYS IN A PRECEDING PROGRAM.

D1 = THE VALUE OF THE INTEGRAL RESULTING FROM USE OF A POSITIVE SIGN IN THE VARIABLE AYS.

D2 = THE VALUE OF THE INTEGRAL RESULTING FROM USE OF A NEGATIVE SIGN IN THE VARIABLE AYS.

DLT03 = THE UPWASH INTERFERENCE FACTOR CALCULATED FOR THE PROGRESSIVELY-MORE-OPEN-PERFORATED-TUNNEL PORTION OF EQUATION (A-4).

ALL OTHER VARIABLE NAMES, EXCEPT AS NOTED, ARE USED MERELY AS BOOKKEEPING DEVICES.

NAMELIST INPUTS ARE BH, BT, RP

```
      PROGRAMWT(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE1,TAPE2,PUNCH)  (B 273)
      COMMONSH(2),IS,YH(3,2),IY,BH,IB,C,PI,RB,AYS,IP                      (B 274)
      DIMENSIONFQ(1),SMQ(1),QNT(1),BH(5),BT(5),RP(4)                      (B 275)
      NAMELIST/INPT/BH,BT,RP$READ(5,INPT)                                 (B 276)
      NQ=4$NFQ=1$JQ=50$PI=3.141592653$CNV=1.E-06$NMY=3                    (B 277)
      DO1IS=1,2$DO1IB=1,5   $SH(1)=.3*BH(IB)$SH(2)=.7*BH(IB)$DO1IP=1,4    (B 278)
      DO1IT=1,5   $RB=RP(IP)/BT(IT)                                       (B 279)
      SB=SH(IS)/BH(IB)$QS=1./SB$WRITE(6,2)BH(IB),SB,RB                    (B 280)
    2 FORMAT(1H ,///6X4HB/H=F7.3,10X4HS/B=F7.3,10X*R/BETA=*F7.3,//5X3HY/  (B 281)
     1S,7X*DELTA SUB 03*//)                                               (B 282)
      DO1IY=1,NMY$YH(IY,IS)=SH(IS)*FLOAT(IY-1)/FLOAT(NMY-1)               (B 283)
```

IN THIS PROGRAM, THE INTEGRATION INTERVAL QNC IS A FUNCTION OF THE VARIABLE AYS ANALOGOUSLY TO AND FOR THE SAME REASONS THAT THE INTEGRATION INTERVAL QNC IS A FUNCTION OF THE VARIABLE ARGYS IN THE PRECEDING PROGRAM FOR DLTC3.

```
      AYS=YH(IY,IS)+SH(IS)$QNC=PI/ABS(AYS)$YS=YH(IY,IS)/SH(IS)            (B 284)
      CALLINFINTQ(NQ,SMQ,FQ,NFQ,JQ,QNC,CNV,QNT)$D1=QNT                    (B 285)
```

IF IY=1, YH=0 AND AYS IS THE SAME IN BOTH INTEGRALS. IF IY=NMY, AYS=0 AND THE INTEGRAL IS ZERO.

```
   IF(IY.EQ.1)GOTO6                                             (B 286)
   IF(IY.EQ.NMY)GOTO4$AYS=SH(IS)-YH(IY,IS)$QNC=PI/ABS(AYS)      (B 287)
   CALLINFINTQ(NQ,SMQ,FQ,NFQ,JQ,QNC,CNV,QNT)$D2=QNT$GOTO5       (B 288)
 6 D2=D1$GOTO5                                                  (B 289)
 4 D2=0.                                                        (B 290)
 5 DLTO3=-BS*(D1+D2)/(2.*PI*PI)$WRITE(6,3)YS,DLTO3              (B 291)
   PUNCH7,SB,BH(IB),RB,YS,DLTO3                                 (B 292)
 7 FORMAT(3(F7.3),F6.2,F10.6)                                   (B 293)
 3 FORMAT(4XF6.2,6XF10.6)                                       (B 294)
 1 CONTINUE$STOP$END                                            (B 295)
```

SUBROUTINE FUNCQ IS ONE WRITTEN TO EVALUATE THE INTEGRAND OF INTEREST OVER THE VARIABLE Q IN ACCORDANCE WITH THE INTEGRATION SUBROUTINE MGAUSQ. REFER TO DISCUSSION IN A PRECEDING PROGRAM.

```
    SUBROUTINE FUNCQ(Q,FQ)$DIMENSIONFQ(1),SMR(2),FR(2),RNT(2),BH(5)   (B 296)
   COMMONSH(2),IS,YH(3,2),IY,BH,IB,S,PI,RB,AYS,IP$S=Q$NR=3$NFR=2      (B 297)
```

IN THIS PROGRAM, THE INTEGRATION INTERVAL RNC IS MADE A FUNCTION OF THE VARIABLE RB AND THE INDEXING INTEGER IP FOR THE SAME REASONS THAT THE INTEGRATION INTERVAL QNC WAS MADE A FUNCTION OF THE SAME VARIABLES IN THE PRECEDING PROGRAM FOR DLTO2.

```
   RNC=5.*RB/IP$CNV=1.E-07$JR=100                               (B 298)
   CALLINFINTR(NR,SMR,FR,NFR,JR,RNC,CNV,RNT)$SYQ=AYS*Q          (B 299)
   FQ=SIN(SYQ)*(Q*RNT(1)+RNT(2)/(RB*RB*Q))$RETURN$END           (B 300)
```

SUBROUTINE FUNCR IS ONE WRITTEN TO EVALUATE THE INTEGRAND OF INTEREST OVER THE VARIABLES Q AND R IN ACCORDANCE WITH THE INTEGRATION SUBROUTINES INFINTQ, INFINTR, MGAUSQ, AND MGAUSR.

```
    SUBROUTINE FUNCR(R,FR)$DIMENSION FR(2),BH(5)                (B 301)
   COMMONSH(2),IS,YH(3,2),IY,BH,IB,Q,PI,RB,AYS                  (B 302)
   AR=SQRT(R*R/(RB*RB)+Q*Q)$BR1=1./(RB*RB)+1.                   (B 303)
   FR(1)=1./((BR1*R*R+Q*Q)*COSH(AR)*COSH(AR)-R*R)               (B 304)
   FR(2)=1./((BR1+Q*Q/(R*R))*COSH(AR)*COSH(AR)-1.)$RETURN$END   (B 305)

$INPT BH=.5,.75,1.,1.5,2.,BT=1.,.8,.6,.45,.3,RP=.1,.45,2.,7.5,$  (B 358)
```

THIS PROGRAM MAKES USE OF THE SUBROUTINE SUBPROGRAMS INFINTQ, INFINTR, MGAUSQ, AND MGAUSR AS DEFINED AND DISCUSSED IN PRECEEDING PROGRAMS.

APPENDIX B

FORTRAN PROGRAM FOR EVALUATING EQUATION (A-13) OF APPENDIX A. THE CALCULATIONS GIVE AN APPROXIMATION CLOSE TO THE SIMULTANEOUS ORIGIN OF THE THREE VARIABLES OF INTEGRATION TO THE UPWASH INTERFERENCE FACTORS FOR WINGS CENTER-MOUNTED IN PROGRESSIVELY-MORE-OPEN-PERFORATED TEST SECTIONS. THE INTERFERENCE FACTORS CALCULATED REPRESENT THE EFFECT OF HORIZONTAL BOUNDARIES ON THE INTERFERENCE VELOCITY POTENTIAL INSIDE THE TEST SECTION DUE TO VERTICAL BOUNDARIES.

IN ADDITION TO THE COMMON VARIABLE NAMES ALREADY DEFINED, THE FOLLOWING NAMES ARE OF IMPORTANCE TO THIS PARTICULAR PROGRAM.

D4 = THE UPWASH INTERFERENCE FACTOR CALCULATED.

EPS1 = A SMALL NUMBER, EPSILON-SUB-1 IN EQUATION (A-13).

EPS2 = A SMALL NUMBER, EPSILON-SUB-2 IN EQUATION (A-13).

ALL OTHER VARIABLE NAMES, EXCEPT AS NOTED, ARE USED MERELY AS BOOKKEEPING DEVICES.

NAMELIST INPUTS ARE BH, BT, RP

```
      PROGRAMWT(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE1,TAPE2,PUNCH)
      DIMENSION BH(5),BT(5),RP(4)
      NAMELIST/INPT/BH,BT,RP$READ(5,INPT)
      PI=3.14159265$EPS1=EPS2=.01$WRITE(6,3)$WRITE(2,3)
    3 FORMAT(1H ,//5X3HB/H,5X6HRP/BETA8X2HD4,//)
      DO1 IB=1,5$DO1 IP=1,4$DO1 IT=1,5$RB=RP(IP)/BT(IT)$RBH=RB/BH(IB)
      RBS=RBH*RBH$AR1=SQRT(EPS2*EPS2+RBS)
      AR=EPS2*AR1+RBS*ALOG(EPS2+AR1)-RBS*ALOG(RBH)-EPS2*EPS2
      D4=EPS1*RB*AR/(2.*PI*PI*RBS)$WRITE(6,2)BH(IB),RB,D4
      WRITE(2,2)BH(IB),RB,D4
    2 FORMAT(2(1XF7.3,2X),F12.8)
      PUNCH4,BH(IB),RB,D4
    4 FORMAT(2(F7.3),F10.8)
    1 CONTINUE$STOP$END

$INPT BH=.5,.75,1.,1.5,2.,BT=1.,.8,.6,.45,.3,RP=.1,.45,2.,7.5,$
```

APPENDIX B

FORTRAN PROGRAM FOR EVALUATING THE FIRST TRIPLE-INTEGRAL PORTION OF EQUATION (A-14) OF APPENDIX A. THIS CALCULATION BEGINS AT THE POINT THE IMMEDIATELY PRECEDING PROGRAM LEFT-OFF AND CARRIES THE INTEGRATION THROUGH PART OF THE REMAINDER OF THE INTEGRATION RANGE. THE CALCULATIONS GIVE AN APPROXIMATION AWAY FROM THE SIMULTANEOUS ORIGIN OF THE THREE INTEGRATION VARIABLES TO THE UPWASH INTERFERENCE FACTORS FOR WINGS CENTER-MOUNTED IN PROGRESSIVELY-MORE-OPEN PERFORATED TEST SECTIONS. THE INTERFERENCE FACTORS CALCULATED REPRESENT THE EFFECT OF HORIZONTAL BOUNDARIES ON THE INTERFERENCE VELOCITY POTENTIAL INSIDE THE TEST SECTION DUE TO VERTICAL BOUNDARIES.

IN ORDER TO COMPARE WITH EQUATION (A-14) OF APPENDIX A, NOTE THE FOLLOWING EQUIVALENCES.

≠Q≠ OF THIS PROGRAM = GREEK LETTER ≠THETA≠ OF EQUATION (A-14).

≠P≠ OF THIS PROGRAM = GREEK LETTER ≠RHO≠ OF EQUATION (A-14).

IN ADDITION TO THE COMMON VARIABLE NAMES ALREADY DEFINED, THE FOLLOWING NAMES ARE OF IMPORTANCE TO THIS PARTICULAR PROGRAM.

DLTO4 = THE UPWASH INTERFERENCE FACTOR RESULTING FROM THE CALCULATIONS OF THIS PROGRAM.

ALL OTHER VARIABLE NAMES, EXCEPT AS NOTED, ARE USED MERELY AS BOOKKEEPING DEVICES.

NAMELIST INPUTS ARE BH, BT, RP

```
  PROGRAMWT(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE1,TAPE2,PUNCH)  (B 374)
  COMMONSH(2),IS,YH(3,2),IY,BH(5),IB,Q,R,PI,RB,AYS                    (B 375)
  DIMENSIONFQ(1),SMQ(1),BT(5),RP(4)                                   (B 376)
  NAMELIST/INPT/BH,BT,RP$READ(5,INPT)                                 (B 377)
  NFQ=1$PI=3.14159265 36$NMY=3$AQ=0.$BQ=PI/2.                         (B 378)
  DO1IS=1,2$DO1IB=1,5$SH(1)=.3*BH(IB)$SH(2)=.7*BH(IB)$DO1IP=1,4       (B 379)
  DO1IT=1,5$RB=RP(IP)/BT(IT)$NQ=1+IFIX(RB/4.)                         (B 380)
  SB=SH(IS)/BH(IB)$BS=1./SB$WRITE(6,2)BH(IB),SB,RB                    (B 381)
  WRITE(2,2)BH(IB),SB,RB$C=RB*BS/(PI*PI*PI)                           (B 382)
2 FORMAT(1H ,///5X4HB/H=F7.3,10X4HS/B=F7.3,10X*R/BETA=*F7.3,//5X3HY/  (B 383)
 1S,5X*DELTA SUP 04*//)                                               (B 384)
  DO1IY=1,NMY$YH(IY,IS)=SH(IS)*FLOAT(IY-1)/FLOAT(NMY-1)               (B 385)
  YS=YH(IY,IS)/SH(IS)$CALLMGAUSQ(AQ,BQ,NQ,SMQ,FQ,NFQ)$DLTO4=C*SMQ(1)  (B 386)
  WRITE(6,3)YS,DLTO4$WRITE(2,3)YS,DLTO4                               (B 387)
3 FORMAT(2XF6.2,5XF10.8)                                              (B 388)
  PUNCH4,SB,BH(IB),RB,YS,DLTO4                                        (B 389)
4 FORMAT(3(F7.3),F6.2,F10.6)                                          (B 390)
1 CONTINUE$STOP$END                                                   (B 391)
```

SUBROUTINE FUNCQ IS ONE WRITTEN TO EVALUATE THE INTEGRAND OF INTEREST OVER THE VARIABLE Q IN ACCORDANCE WITH THE INTEGRATION SUBROUTINE MGAUSQ. REFER TO DISCUSSION IN A PRECEDING PROGRAM.

```
  SUBROUTINE FUNCQ(Q,FQ)$DIMENSIONFQ(1),FR(1),RNT(1)
  COMMONSH(2),IS,YH(3,2),IY,BH(5),IB,S,R,PI,RB,AYS$S=Q$NR=1$NFR=1
  JR=50$CNV=1.E-05$AYS=YH(IY,IS)+BH(IB)$RNC=PI/ABS(AYS)
  CALLINFINTR(NR,FR,NFR,JR,RNC,CNV,RNT)$D41=RNT(1)
  IF(IY.EQ.1)GOTO6$AYS=BH(IB)-YH(IY,IS)$RNC=PI/ABS(AYS)
  CALLINFINTR(NR,FR,NFR,JR,RNC,CNV,RNT)$D42=RNT(1)$GOTO5
6 D42=D41
5 FQ(1)=COS(Q)*(D41+D42)$RETURN$END
```

SUBROUTINE FUNCR IS ONE WRITTEN TO EVALUATE THE INTEGRAND OF INTEREST OVER THE VARIABLES Q AND R IN ACCORDANCE WITH THE INTEGRATION SUBROUTINES INFINTR, MGAUSQ, AND MGAUSR.

```
  SUBROUTINE FUNCR(R,FR)$DIMENSIONFR(1),FP(1),PNT(1)
  COMMONSH(2),IS,YH(3,2),IY,BH(5),IB,Q,T,PI,RB,AYS
  T=R$NFP=1$JP=50$CNV=5.E-05$PNC=PI/(2.*COS(Q))
  IF(PNC.GT.(2.*PI))PNC=2.*PI$NP=IFIX(PNC*2./PI)$IF(NP.LT.1)NP=1
  CALLINFINTP(NP,FP,NFP,JP,PNC,CNV,PNT)$FR(1)=PNT(1)$RETURN$END
```

SUBROUTINE FUNCP IS ONE WRITTEN TO EVALUATE THE INTEGRAND OF INTEREST OVER THE VARIABLES P, Q, AND R IN ACCORDANCE WITH THE INTEGRATION SUBROUTINES INFINTP, INFINTR, MGAUSP, MGAUSQ, AND MGAUSR.

```
  SUBROUTINE FUNCP(P,FP)$DIMENSIONFP(1)
  COMMONSH(2),IS,YH(3,2),IY,BH(5),IB,Q,R,PI,RB,AYS
  BP=BH(IB)*P$SP=SH(IS)*P$A1=SQRT(P*P*SIN(Q)*SIN(Q)+R*R)$A2=P*COS(Q)
  AR=AYS*R$SNAR=AR$IF(AR.GT..05)SNAR=SIN(AR)$CSAR=COS(AR)
  SHBP=BP$IF(BP.GT..05)SHBP=SINH(BP)$CHBP=COSH(BP)
  AN=(P*SHBP*CSAR+R*CHBP*SNAR)/(P*P+R*R)$SNQ=Q
  IF(Q.GT..05)SNQ=SIN(Q)$D1=SHBP*SHBP+RB*RB*SNQ*SNQ*CHBP*CHBP
  SHA1=1.$IF(A1.GT..05)SHA1=SINH(A1)/A1$CHA1=COSH(A1)
  D2=(RB*P*SNQ*SHA1)**2.+CHA1**2.$TR1=SINH(SP)*AN/(EXP(BP)*D1*D2)
  SNA2=A2$IF(A2.GT..05)SNA2=SIN(A2)$CSA2=COS(A2)$CSQ=COS(Q)
  A3=((RB*SNQ)**2.)*P*SNA2*SHA1+CSQ*CSA2*CHA1
  A4=SHBP-RB*RB*SNQ*SNQ*CHBP$A5=A2*CSA2*SHA1-SNA2*CHA1
  FP(1)=TR1*(EXP(BP)*A3+A4*A5)$RETURN$END
```

APPENDIX B

THE SUBROUTINE SUBPROGRAMS INFINTP AND MGAUSP IN THIS PROGRAM ARE NECESSARY TO ALLOW INTEGRATIONS OVER THREE VARIABLES RATHER THAN THE TWO VARIABLES OF PRECEDING PROGRAMS. EXCEPTING FOR THE SUBROUTINE NAMES AND WHATEVER VARIABLE NAME-CHANGES ARE NECESSARY TO ALLOW THE CALCULATIONS TO PROCEED WITHOUT CONFUSION, THEY ARE IDENTICAL WITH THE SUBROUTINES INFINTQ AND MGAUSQ AS DISCUSSED IN A PRECEDING PROGRAM. ALSO NOTE THAT THE INITIAL VALUE OF THE LOWER LIMIT ≠AQ≠ HAS BEEN CHANGED FROM ZERO TO 0.01 IN ACCORDANCE WITH THE LIMITS ON THE INTEGRALS BEING PROGRAMMED.

```
   SUBROUTINE INFINTP(NQ,FOFP,NFQ,JQ,QINC,CONV,QINT)                (B 418)
  DIMENSION SUMQ(1),FOFP(1),QINT(1) $DO1I=1,NFQ                     (B 419)
1 QINT(I)=0.$AQ=.01$DO2IQ=1,JQ$IF(IQ-1)4,4,3                        (B 420)
3 AQ=BQ$GOTO9                                                       (B 421)
4 BQ=0.                                                             (B 422)
9 BQ=BQ+QINC$CALLMGAUSP(AQ,BQ,NQ,SUMQ,FOFP,NFQ)                     (B 423)
  QCONV=0.$DO5I=1,NFQ$QCONV=QCONV+ABS(SUMQ(I))                      (B 424)
5 QINT(I)=QINT(I)+SUMQ(I)$IF(QCONV.LT.CONV)GOTO6$IF(IQ.EQ.JQ)GOTO7  (B 425)
  GOTO2                                                             (B 426)
7 WRITE(6,8)$WRITE(2,8)$GOTO6                                       (B 427)
8 FORMAT(1H ,2X*INTEGRAL NONCONVERGENT WITH GIVEN UPPER LIMIT ON P*) (B 428)
2 CONTINUE                                                          (B 429)
6 RETURN$END                                                        (B 430)


   SUBROUTINE MGAUSP(A,B,N,SUM,FOFX,NUMBER)                         (B 443)
  DIMENSION U(5),R(5),SUM(1),FOFX(1)$DO1LL=1,NUMBER                 (B 444)
1 SUM(LL)=0.0                                                       (B 445)
  IF(A.EQ.B)RETURN$U(1)=.425562830509184$U(2)=.283302302985376      (B 446)
  U(3)=.160295215850488$U(4)=.067468316655508$U(5)=.013046735741414 (B 447)
  R(1)=.147762112357376$R(2)=.134633359654998$R(3)=.109543181257991 (B 448)
  R(4)=.074725674575290$R(5)=.033335672154344$FINE=N                (B 449)
  DELTA=FINE/(B-A)$DO3K=1,N$XI=K-1$FINE=A+XI/DELTA$DO2II=1,5        (B 450)
  UU=U(II)/DELTA+FINE$CALLFUNCP(UU,FOFX)$DO2JOYBOY=1,NUMBER         (B 451)
2 SUM(JOYBOY)=R(II)*FOFX(JOYBOY)+ SUM(JOYBOY)$DO3JJ=1,5             (B 452)
  UU=(1.0-U(JJ))/DELTA+FINE$CALLFUNCP(UU,FOFX)$DO3NN=1,NUMBER       (B 453)
3 SUM(NN)=R(JJ)*FOFX(NN)+SUM(NN)$DO7IJK=1,NUMBER                    (B 454)
7 SUM(IJK)=SUM(IJK)/DELTA $RETURN$END                               (B 455)

$INPT BH=.5,.75,1.,1.5,2.,BT=1.,.8,.6,.45,.3,RP=.1,.45,2.,7.5,$     (B 482)
```

THIS PROGRAM MAKES USE OF THE SUBROUTINE SUBPROGRAMS INFINTR, MGAUSQ, AND MGAUSR AS DEFINED AND DISCUSSED IN PRECEEDING PROGRAMS.

APPENDIX B

FORTRAN PROGRAM FOR EVALUATING THE SECOND TRIPLE-INTEGRAL PORTION OF EQUATION (A-14) OF APPENDIX A. THIS CALCULATION BEGINS AT THE POINT THE IMMEDIATELY PRECEDING PROGRAM LEFT-OFF AND CARRIES THE INTEGRATION THROUGH THE REMAINDER OF THE INTEGRATION RANGE. EXCEPT FOR THE LIMITS OF INTEGRATION, THIS PROGRAM IS IDENTICAL WITH THE PROGRAM IMMEDIATELY PRECEDING. ONLY THE PORTION SHOWING THE CHANGE IN THE LIMITS OF INTEGRATION IS REPRODUCED HERE.

```
 SUBROUTINE FUNCR(R,FR)$DIMENSIONFR(1),FP(1)                      (B 509)
COMMONSH(2),IS,YH(3,2),IY,BH(5),IE,Q,T,PI,RB,AYS                  (B 510)
```

SINCE THE INTEGRATION LIMITS ON THIS INTEGRAL ARE FINITE RATHER THAN INFINITE AS WITH THE INTEGRAL OF THE PROGRAM IMMEDIATELY PRECEDING, THE SUBROUTINE INFINTR IS NOT USED IN THIS PROGRAM.

```
T=R$NFP=1$NP=1$AP=0.$BP=.01$CALLMGAUSP(AP,BP,NP,FR(1),FP,NFP)     (B 511)
RETURN$END                                                        (B 512)
```

IN ACCORDANCE WITH THE INTEGRATION LIMITS OF EQUATION (A-14) OF APPENDIX A, THE INITIAL VALUE FOR THE LOWER LIMIT AQ IN THE SUBROUTINE INFINTR IS SET AT 0.01 RATHER THAN ZERO.

APPENDIX B

FORTRAN PROGRAM FOR COLLATING DATA. THE PUNCHED-CARD OUTPUT OF THE THREE PRECEDING PROGRAMS IS THE INPUT TO THIS PROGRAM. THE DATA ARE COLLATED, PRINTED OUT AS A CHECK, THEN PUNCHED ONTO DATA-PROCESSING CARDS FOR LATER COLLATION WITH THE DATA REPRESENTING WINGS CENTER-MOUNTED IN CLOSED, RECTANGULAR, PERFORATED TEST-SECTIONS AND WITH THE DATA REPRESNTING VARIOUS COMPONENTS OF UPWASH INTERFERENCE FACTORS FOR WINGS CENTER-MOUNTED IN PROGRESSIVELY-MORE-OPEN, RECTANGULAR, PERFORATED TEST-SECTIONS. THE COLLATED DATA OF THIS PROGRAM GIVE THE TOTAL COMPONENT FOR PROGRESSIVELY-MORE-OPEN TEST-SECTIONS OF UPWASH INTERFERENCE FACTORS DUE TO THE EFFECT OF HORIZONTAL BOUNDARIES ON THE INTERFERENCE VELOCITY POTENTIAL INSIDE THE TEST-SECTION DUE TO VERTICAL BOUNDARIES.

IN ADDITION TO THE COMMON VARIABLE NAMES ALREADY DEFINED, THE FOLLOWING NAMES ARE OF IMPORTANCE TO THIS PARTICULAR PROGRAM.

D41 = D4 OF THE PROGRAM EVALUATING EQUATION (A-13) OF APPENDIX A.

D42 = DLTO4 OF THE PROGRAM EVALUATING THE FIRST TRIPLE-INTEGRAL PORTION OF EQUATION (A-14) OF APPENDIX A.

D43 = DLTO4 OF THE PROGRAM EVALUATING THE SECOND TRIPLE-INTEGRAL PORTION OF EQUATION (A-14) OF APPENDIX A.

D45 = THE RESULT OF COLLATION OF THE FACTORS D41, D42, AND D43 INTO THE UPWASH INTERFERENCE FACTOR REPRESENTING WINGS CENTER-MOUNTED IN PROGRESSIVELY-MORE-OPEN, RECTANGULAR, PERFORATED TEST-SECTIONS DUE TO THE EFFECT OF HORIZONTAL BOUNDARIES ON THE INTERFERENCE VELOCITY POTENTIAL INSIDE THE TEST-SECTION DUE TO VERTICAL BOUNDARIES.

ALL OTHER VARIABLE NAMES, EXCEPT AS NOTED, ARE USED MERELY AS BOOKKEEPING DEVICES.

```
      PROGRAMWT(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,PUNCH)
      DIMENSION BH1(100),BH2(600),BH3(600),RB1(100),RB2(600),RB3(600)
      DIMENSION SB2(600),SB3(600),YS2(600),YS3(600),D41(100),D42(600)
      DIMENSION D43(600),D44(600),D45(600)
      READ(5,1)(BH1(I),RB1(I),D41(I),I=1,100)
    1 FORMAT(2(F7.3),F10.8)
      READ(5,2)(SB2(I),BH2(I),RB2(I),YS2(I),D42(I),I=1,600)
      READ(5,2)(SB3(I),BH3(I),RB3(I),YS3(I),D43(I),I=1,600)
    2 FORMAT(3(F7.3),F6.2,F10.6)
      WRITE(6,3)$WRITE(6,1)(BH1(I),RB1(I),D41(I),I=1,100)
    3 FORMAT(2X*B/H*3X*R/BETA*3X*DLT41*//)
      WRITE(6,4)$WRITE(6,2)(SB2(I),BH2(I),RB2(I),YS2(I),D42(I),I=1,600)
      WRITE(6,5)$WRITE(6,2)(SB3(I),BH3(I),RB3(I),YS3(I),D43(I),I=1,600)
    4 FORMAT(///2X*S/B*4X*B/H*3X*R/BETA*2X*Y/S*4X*DLT42*//)
    5 FORMAT(///2X*S/B*4X*B/H*3X*R/BETA*2X*Y/S*4X*DLT43*//)
      J=0$DO6IS=1,2$DO6I=1,100$DO6K=1,3$J=J+1$D44(J)=D41(I)
    6 D45(J)=D44(J)+D42(J)+D43(J)
      WRITE(6,7)$WRITE(6,8)(SB3(I),BH3(I),RB3(I),YS3(I),D42(I),D43(I),D4
     14(I),D45(I),I=1,600)
    7 FORMAT(///2X*S/B*4X*B/H*3X*R/BETA*2X*Y/S*4X*DLT42*5X*DLT43*5X*DLT4
     14*5X*DLT45*//)
    8 FORMAT(3(F7.3),F6.2,4(F10.6))
      PUNCH 2,(SB3(I),BH3(I),RB3(I),YS3(I),D45(I),I=1,600)
      STOP$END
```

APPENDIX B

FORTRAN PROGRAM FOR EVALUATING EQUATION (A-10) OF APPENDIX A. THE RESULTS GIVE UPWASH INTERFERENCE FACTORS FOR WINGS CENTER-MOUNTED IN PROGRESSIVELY-MORE-OPEN, RECTANGULAR, PERFORATED TEST-SECTIONS DUE TO THE EFFECT OF HORIZONTAL BOUNDARIES ON THE INTERFERENCE VELOCITY POTENTIAL OUTSIDE THE TEST-SECTION DUE TO HORIZONTAL BOUNDARIES.

IN ADDITION TO THE COMMON VARIABLE NAMES ALREADY DEFINED, THE FOLLOWING NAMES ARE OF IMPORTANCE TO THIS PARTICULAR PROGRAM.

DLTO5 = THE UPWASH INTERFERENCE FACTOR CALCULATED

ALL OTHER VARIABLE NAMES, EXCEPT AS NOTED, ARE USED MERELY AS BOOKKEEPING DEVICES.

NAMELIST INPUTS ARE BH, BT, RP

```
      PROGRAMWT(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE1,TAPE2,PUNCH)  (B 578)
      COMMONSH(2),IS,YH(3,2),IY,BH,IB,F,G,PI,RB,AYS,IP,BP,BPG,PQ,BG,NMY   (B 579)
      DIMENSIONFQ(1),SMQ(1),QNT(1),BH(5),BT(5),RP(4)                      (B 580)
      NAMELIST/INPT/BH,BT,RP$READ(5,INPT)                                 (B 581)
      NQ=1$NFQ=1$JQ=50$PI=3.1415926536$CNV=2.E-03$NMY=3$QNC=PI            (B 582)
      DO1IS=2,2$DO1IB=3,3$SH(1)=.3*BH(IB)$SH(2)=.7*BH(IB)$DO1IP=3,4       (B 583)
      DO1IT=1,5$RB=RP(IP)/BT(IT)                                          (B 584)
      SB=SH(IS)/BH(IB)$RS=1./SB$WRITE(6,2)BH(IB),SB,RB                    (B 585)
      WRITE(2,2)BH(IB),SB,RB$C=RS/(PI*PI*PI)                              (B 586)
    2 FORMAT(1H ,///6X4HB/H=F7.3,10X4HS/B=F7.3,10X*R/BETA=*F7.3,//5X3HY/  (B 587)
     1S,5X*DELTA SUB 05*//)                                               (B 588)
      DO1IY=1,NMY$YH(IY,IS)=SH(IS)*FLOAT(IY-1)/FLOAT(NMY-1)               (B 589)
      YS=YH(IY,IS)/SH(IS)                                                 (B 590)
      CALLINFINTG(NQ,SMQ,FQ,NFQ,JQ,QNC,CNV,QNT)$DLTO5=C*QNT(1)            (B 591)
      WRITE(6,3)YS,DLTO5$WRITE(2,3)YS,DLTO5                               (B 592)
    3 FORMAT(2XF6.2,5XF10.6)                                              (B 593)
      PUNCH4,SB,BH(IB),RB,YS,DLTO5                                        (B 594)
    4 FORMAT(3(F7.3),F6.2,F10.6)                                          (B 595)
    1 CONTINUE$STOP$END                                                   (B 596)
```

APPENDIX B

SUBROUTINE FUNCQ IS ONE WRITTEN TO EVALUATE THE INTEGRAND OF INTEREST OVER THE VARIABLE Q IN ACCORDANCE WITH THE INTEGRATION SUBROUTINE MGAUSQ. REFER TO DISCUSSION IN A PRECEDING PROGRAM.

```
 SUBROUTINE FUNCQ(Q,FQ)$DIMENSIONFQ(1),SMP(1),FP(1),PNT(1),BH(5)    (B 597)
COMMONSH(2),IS,YH(3,2),IY,BH,IB,F,S,PI,RB,AYS,IP,BP,BPQ,PQ,BQ,NMY   (B 598)
NP=3$NFP=1$PNC=5.*RB*FLOAT(IS)/FLOAT(IP)$CNV=1.E-03$JP=50$S=Q       (B 599)
CALLINFINTP(NP,SMP,FP,NFP,JP,PNC,CNV,PNT)$FQ(1)=Q*PNT(1)            (B 600)
RETURN$END                                                          (B 601)
```

SUBROUTINE FUNCP IS ONE WRITTEN TO EVALUATE THE INTEGRAND OF INTEREST OVER THE VARIABLES P AND Q IN ACCORDANCE WITH THE INTEGRATION SUBROUTINES INFINTP, INFINTQ, MGAUSP, AND MGAUSQ.

```
 SUBROUTINE FUNCP(P,FP)$DIMENSIONFP(1),FR(1),SMR(1),RNT(1),BH(5)    (B 602)
COMMONSH(2),IS,YH(3,2),IY,BH,IB,T,Q,PI,RB,AYS,IP,BP,BPQ,PQ,BQ,NMY   (B 603)
T=P$NR=1$NFR=1$JR=50$CNV=5.E-04$BPQ=SQRT(P*P/(RB*RB)+Q*Q)           (B 604)
BP=(1.+1./(RB*RB))*P*P$PQ=BP+Q*Q$SQ=SH(IS)*BPQ$BQ=BH(IB)*BPQ        (B 605)
A1=SINH(SQ)/(EXP(BQ)*BPQ*BPQ)                                       (B 606)
AYS=YH(IY,IS)+BH(IB)$RNC=PI/ABS(AYS)                                (B 607)
CALLINFINTR(NR,SMR,FR,NFR,JR,RNC,CNV,RNT)$D51=RNT(1)                (B 608)
IF(IY.EQ.1)GOTO6$AYS=BH(IB)-YH(IY,IS)$RNC=PI/ABS(AYS)               (B 609)
CALLINFINTR(NR,SMR,FR,NFR,JR,RNC,CNV,RNT)$D52=RNT(1)                (B 610)
GOTO5                                                               (B 611)
6 D52=D51                                                           (B 612)
5 FP(1)=A1*(D51+D52)$RETURN$END                                     (B 613)
```

SUBROUTINE FUNCR IS ONE WRITTEN TO EVALUATE THE INTEGRAND OF INTEREST OVER THE VARIABLES P, Q, AND R IN ACCORDANCE WITH THE INTEGRATION SUBROUTINES INFINTP, INFINTQ, INFINTR, MGAUSP, MGAUSQ, AND MGAUSR.

```
 SUBROUTINE FUNCR(R,FR)$DIMENSIONFR(1),BH(5)                        (B 614)
COMMONSH(2),IS,YH(3,2),IY,BH,IB,P,Q,PI,RB,AYS,IP,BP,BPQ,PQ,BQ,NMY   (B 615)
BPR=SQRT(P*P/(RB*RB)+R*R)$SR=SH(IS)*BPR$BYR=AYS*R$BPQR=BPQ*BPQ+R*R  (B 616)
PR=BP+R*R$A1=BPR*BPR/(BPQR*(PR*COSH(BPR)*COSH(BPR)-P*P))            (B 617)
A51=SIN(Q)*COSH(BPR)-Q*COS(Q)*SINH(BPR)/BPR                         (B 618)
A52=BPQ*COS(BYR)-R*SIN(BYR)$FR(1)=A1*A51*A52$RETURN$END             (B 619)

$INPT BH=.5,.75,1.,1.5,2.,BT=1.,.8,.6,.45,.3,RF=.1,.45,2.,7.5,$     (B 695)
```

THIS PROGRAM MAKES USE OF THE SUBROUTINE SUBPROGRAMS INFINTP, INFINTQ, INFINTR, MGAUSP, MGAUSQ, AND MGAUSR AS DEFINED AND DISCUSSED IN PRECEDING PROGRAMS.

APPENDIX B

FORTRAN PROGRAM FOR COLLATING THE DATA CALCULATED BY MEANS OF EQUATIONS (A-2), (A-4), (A-7), (A-8), (A-10), (A-13), AND (A-14) OF APPENDIX A. THE PUNCHED-CARD OUTPUT OF SEVERAL PRECEDING PROGRAMS IS THE INPUT TO THIS PROGRAM. THE DATA ARE COMBINED, PRINTED-OUT AS A CHECK, THEN PUNCHED ONTO DATA-PROCESSING CARDS FOR USE IN A PROGRAM WHICH GENERATES FINAL TABLES OF THE DATA.

IN ADDITION TO THE COMMON VARIABLE NAMES ALREADY DEFINED, THE FOLLOWING NAMES ARE OF IMPORTANCE TO THIS PARTICULAR PROGRAM.

DLT2 = THE UPWASH INTERFERENCE FACTOR DELTA-SUB-2 OF EQUATION (A-2) OF APPENDIX A.

DLT3 = THE UPWASH INTERFERENCE FACTOR DELTA-SUB-3 OF EQUATION (A-4) OF APPENDIX A.

DLT4 = THE UPWASH INTERFERENCE FACTOR DELTA-SUB-4 OF EQUATION (A-14) OF APPENDIX A.

DLT5 = THE UPWASH INTERFERENCE FACTOR DELTA-SUB-5 OF EQUATION (A-10) OF APPENDIX A.

DLTT = THE TOTAL UPWASH INTERFERENCE FACTOR, THE SUMMATION OF DLT2, DLT3, DLT4, AND DLT5.

ALL OTHER VARIABLE NAMES, EXCEPT AS NOTED, ARE USED MERELY AS BOOKKEEPING DEVICES.

```
      PROGRAMWT(INPUT,OUTPUT,PUNCH)
      DIMENSION SBC(30),BHC(30),YSC(30),D2C(30),D3C(30),D4C(30),D5C(30)
      DIMENSION SBO(600,4),BHO(600,4),RBO(600,4),YSO(600,4),DLT(600,4)
      DIMENSION DLT2(600),DLT3(600),DLT4(600),DLT5(600),DLTT(600)
      READ1,(SBC(I),BHC(I),YSC(I),D2C(I),D3C(I),D4C(I),D5C(I),I=1,30)
    1 FORMAT(2(F7.3),F6.2,4(F12.6))
      PRINT2
    2 FORMAT(2X*S/B*4X*B/H*3X*Y/S*5X*DLTC2*7X*DLTC3*7X*DLTC4*7X*DLTC5*/)
      PRINT1,(SBC(I),BHC(I),YSC(I),D2C(I),D3C(I),D4C(I),D5C(I),I=1,30)
      READ3,((SBO(I,J),BHO(I,J),RBO(I,J),YSO(I,J),DLT(I,J),I=1,600),J=1,
     14)
    3 FORMAT(3(F7.3),F6.2,F10.6)
      DO4J=1,4$L=J+1
      PRINT5,L,(SBO(I,J),BHO(I,J),RBO(I,J),YSO(I,J),DLT(I,J),I=1,600)
    5 FORMAT(///2X*S/B*4X*B/H*2X*R/BETA*2X*Y/S*2X*DELTA SUB O*I1,//(3(F7
     1.3),F6.2,F10.6))
    4 CONTINUE
      J=0$DO6I=1,10$MC=(I-1)*3+1$NC=MC+2$DO6IRB=1,20$DO6IY=MC,NC$J=J+1
      DLT2(J)=D2C(IY)+DLT(J,1)$DLT3(J)=D3C(IY)+DLT(J,2)
      DLT4(J)=D4C(IY)+DLT(J,3)$DLT5(J)=D5C(IY)+DLT(J,4)
    6 DLTT(J)=DLT2(J)+DLT3(J)+DLT4(J)+DLT5(J)
      PRINT7,(SBO(I,1),BHO(I,1),RBO(I,1),YSO(I,1),DLT2(I),DLT3(I),DLT4(I
     1),DLT5(I),DLTT(I),I=1,600)
    7 FORMAT(///2X*S/B*4X*B/H*2X*R/BETA*3X*Y/S*3X*DELTA SUB 2*3X*DELTA S
     1UB 3*3X*DELTA SUB 4*3X*DELTA SUB 5*3X*TOTAL DELTA*//(3(F7.3),F6.2,
     25(3XF8.6,3X)))
      PUNCH8,(SBO(I,1),BHO(I,1),RBO(I,1),YSO(I,1),DLT2(I),DLT3(I),DLT4(I
     1),DLT5(I),DLTT(I),I=1,600)
    8 FORMAT(3F7.3,F6.2,5F10.6)
      STOP$END
```

APPENDIX B

FORTRAN PROGRAM FOR GENERATING TABLES OF THE PREVIOUSLY CALCULATED AND COLLATED DATA. THE DATA OUTPUT FROM THE IMMEDIATELY PRECEDING PROGRAM ARE THE INPUT FOR THIS PROGRAM. THIS PROGRAM ARRANGES THE DATA AND PRINTS THEM IN TABULAR FORM.

IN ADDITION TO THE COMMON VARIABLE NAMES ALREADY DEFINED, THE FOLLOWING NAMES ARE OF IMPORTANCE TO THIS PARTICULAR PROGRAM.

D2 = DLT2 OF THE IMMEDIATELY PRECEDING PROGRAM.

D3 = DLT3 OF THE IMMEDIATELY PRECEDING PROGRAM.

D4 = DLT4 OF THE IMMEDIATELY PRECEDING PROGRAM.

D5 = DLT5 OF THE IMMEDIATELY PRECEDING PROGRAM.

DT = DLTT OF THE IMMEDIATELY PRECEDING PROGRAM.

ALL OTHER VARIABLE NAMES, EXCEPT AS NOTED, ARE USED MERELY AS BOOKKEEPING DEVICES.

```
      PROGRAM WTIN(INPUT,OUTPUT)
      DIMENSION SB(600),BH(600),RB(600),R(600),YS(600),D2(600),D3(600)
      DIMENSION D4(600),D5(600),DT(600),BETA(600)
      DIMENSION X(20,5,2),Y(20,5,2),XP(22),YP(22)
      READ1,(SB(I),BH(I),RB(I),YS(I),D2(I),D3(I),D4(I),D5(I),DT(I),I=1,6
     100)$NBH=-29$NRB=-14$NBET=NYS=-2
    1 FORMAT(3F7.3,F6.2,5F10.6)
      DO2IS=1,2$DO3IBH=1,5$NRB=0$DO4IP=1,2$NBH=NBH+30
      PRINT5,BH(NBH),SB(NBH)$DO6IR=1,10$NBET=NBET+3$NRB=NRB+1
    5 FORMAT(1H1/8X*TUNNEL WIDTH-TO-HEIGHT RATIO, B/H=*F6.2,8X*WING-SPAN
     1-TO-TUNNEL-WIDTH RATIO, S/B=*F6.2///4X*R/BETA*8X*Y/S*9X*DELTA*8X*D
     2ELTA*8X*DELTA*8X*DELTA*8X*TOTAL*5X*DELTA/DELTA*/30X*SUB 2*8X*SUB 3
     3*8X*SUB 4*8X*SUB 5*8X*DELTA*8X*SUB C*//)
      PRINT7,RB(NBET)
      Y(NRB,IBH,IS)=DT(NBET)$X(NRB,IBH,IS)=RB(NBET)$MYS=NBET+2
      PRINT10,(YS(I),D2(I),D3(I),D4(I),D5(I),DT(I),I=NBET,MYS)
    6 CONTINUE
    4 CONTINUE
      PRINT11,(X(I,IBH,IS),Y(I,IBH,IS),I=1,NRB)
    3 CONTINUE
    2 CONTINUE
    7 FORMAT(1H+,1XF7.3)
   10 FORMAT(1H ,16XF4.1,5(7XF6.3)/17XF4.1,5(7XF6.3)/17XF4.1,5(7XF6.3)/)
   11 FORMAT(1H0,1X*R/BETA*6X*TOTAL*/14X*DELTA*//(2XF7.3,3XF6.3))
      STOP$END
```

REFERENCES

1. Wright, Ray H.; and Schilling, Benferd L.: Approximation of the Spanwise Distribution of Wind-Tunnel-Boundary Interference on Lift of Wings in Rectangular Perforated-Wall Test Sections. NASA TR R-285, 1968.

2. Theodorsen, Theodore: Interference on an Airfoil of Finite Span in an Open Rectangular Wind Tunnel. NACA Rep. 461, 1933.

TABLE I.- UPWASH INTERFERENCE FACTORS δ IN RECTANGULAR TEST SECTIONS CALCULATED BY APPROXIMATION PROCEDURE WITH VARYING PERMEABILITY FACTORS FOR WING-SPAN—TEST-SECTION-WIDTH RATIO s/b OF 0.3

(a) Tunnel width-height ratio b/h of 0.50

R/β	y/s	δ_2	δ_3	δ_4	δ_5	Approximated δ $(\delta_2 + \delta_3 + \delta_4 + \delta_5)$
CLOSED	0.0					.266
.100	0.0	.205	.027	-.014	-.002	.216
	.5	.208	.027	-.014	-.002	.219
	1.0	.216	.026	-.014	-.002	.227
.125	0.0	.194	.026	-.012	-.002	.206
	.5	.197	.026	-.012	-.001	.209
	1.0	.205	.025	-.012	-.001	.217
.167	0.0	.178	.023	-.010	-.001	.191
	.5	.180	.023	-.010	-.001	.193
	1.0	.188	.023	-.009	-.001	.201
.222	0.0	.159	.020	-.007	-.000	.172
	.5	.161	.020	-.007	-.000	.174
	1.0	.169	.020	-.007	.000	.181
.333	0.0	.127	.015	-.005	.002	.139
	.5	.129	.015	-.005	.002	.141
	1.0	.135	.014	-.004	.002	.147
.450	0.0	.100	.009	-.003	.003	.109
	.5	.101	.009	-.003	.003	.110
	1.0	.107	.009	-.003	.003	.116
.562	0.0	.078	.004	-.002	.004	.084
	.5	.080	.004	-.002	.004	.086
	1.0	.084	.004	-.002	.005	.090
.750	0.0	.049	-.004	-.001	.006	.051
	.5	.050	-.004	-.001	.006	.052
	1.0	.053	-.004	-.001	.007	.055
1.000	0.0	.021	-.012	.000	.009	.017
	.5	.021	-.012	.000	.009	.018
	1.0	.023	-.012	.000	.009	.019
1.500	0.0	-.017	-.024	.004	.011	-.026
	.5	-.017	-.024	.004	.012	-.026
	1.0	-.018	-.024	.004	.012	-.027
2.000	0.0	-.041	-.032	.008	.013	-.052
	.5	-.041	-.032	.008	.013	-.052
	1.0	-.044	-.032	.007	.013	-.054
2.500	0.0	-.056	-.033	.011	.014	-.069
	.5	-.057	-.037	.011	.014	-.070
	1.0	-.061	-.037	.011	.015	-.073
3.333	0.0	-.074	-.044	.015	.015	-.087
	.5	-.075	-.044	.015	.015	-.088
	1.0	-.079	-.043	.014	.016	-.093
4.444	0.0	-.087	-.049	.020	.016	-.100
	.5	-.089	-.048	.020	.016	-.102
	1.0	-.094	-.048	.019	.017	-.107
6.667	0.0	-.102	-.054	.024	.017	-.116
	.5	-.104	-.054	.024	.017	-.118
	1.0	-.111	-.053	.023	.017	-.124
7.500	0.0	-.106	-.055	.025	.017	-.119
	.5	-.108	-.055	.025	.017	-.121
	1.0	-.114	-.055	.024	.017	-.127
9.375	0.0	-.111	-.057	.027	.017	-.124
	.5	-.113	-.057	.027	.017	-.126
	1.0	-.120	-.056	.026	.017	-.133
12.500	0.0	-.117	-.059	.029	.017	-.130
	.5	-.119	-.059	.029	.017	-.132
	1.0	-.127	-.058	.028	.018	-.139
16.667	0.0	-.121	-.061	.031	.017	-.134
	.5	-.124	-.060	.031	.017	-.136
	1.0	-.131	-.060	.030	.018	-.144
25.000	0.0	-.125	-.062	.033	.017	-.138
	.5	-.128	-.062	.032	.017	-.140
	1.0	-.136	-.061	.032	.018	-.148
OPEN	0.0					-.140

TABLE I.- UPWASH INTERFERENCE FACTORS δ IN RECTANGULAR TEST SECTIONS CALCULATED BY APPROXIMATION PROCEDURE WITH VARYING PERMEABILITY FACTORS FOR WING-SPAN–TEST-SECTION-WIDTH RATIO s/b OF 0.3 - Continued

(b) Tunnel width-height ratio b/h of 0.75

R/β	y/s	δ_2	δ_3	δ_4	δ_5	Approximated δ $(\delta_2 + \delta_3 + \delta_4 + \delta_5)$
CLOSED	0.0					.178
.100	0.0	.137	.040	-.031	.002	.148
	.5	.138	.040	-.031	.002	.150
	1.0	.144	.038	-.030	.002	.155
.125	0.0	.129	.038	-.029	.002	.141
	.5	.131	.038	-.028	.002	.143
	1.0	.137	.036	-.028	.003	.148
.167	0.0	.119	.035	-.025	.003	.131
	.5	.120	.034	-.025	.003	.133
	1.0	.126	.033	-.024	.003	.137
.222	0.0	.106	.030	-.022	.003	.118
	.5	.107	.030	-.021	.003	.119
	1.0	.112	.029	-.021	.004	.124
.333	0.0	.085	.022	-.017	.004	.094
	.5	.086	.021	-.016	.004	.095
	1.0	.090	.020	-.016	.005	.099
.450	0.0	.067	.013	-.013	.005	.072
	.5	.068	.013	-.013	.005	.073
	1.0	.071	.012	-.012	.006	.077
.562	0.0	.052	.006	-.010	.006	.054
	.5	.053	.006	-.010	.006	.055
	1.0	.055	.005	-.010	.007	.058
.750	0.0	.033	-.005	-.006	.007	.029
	.5	.034	-.006	-.006	.007	.029
	1.0	.035	-.006	-.006	.008	.031
1.000	0.0	.014	-.018	-.002	.009	.002
	.5	.014	-.018	-.002	.009	.003
	1.0	.015	-.018	-.002	.009	.004
1.500	0.0	-.011	-.036	.004	.010	-.033
	.5	-.012	-.036	.004	.010	-.033
	1.0	-.012	-.036	.004	.011	-.033
2.000	0.0	-.027	-.048	.010	.011	-.054
	.5	-.028	-.048	.010	.011	-.054
	1.0	-.029	-.047	.010	.012	-.055
2.500	0.0	-.038	-.056	.015	.011	-.068
	.5	-.038	-.056	.014	.012	-.068
	1.0	-.040	-.055	.014	.012	-.069
3.333	0.0	-.049	-.065	.020	.012	-.082
	.5	-.050	-.065	.020	.012	-.083
	1.0	-.053	-.064	.019	.013	-.085
4.444	0.0	-.058	-.073	.026	.012	-.093
	.5	-.059	-.072	.026	.012	-.093
	1.0	-.063	-.071	.026	.013	-.096
6.667	0.0	-.068	-.080	.032	.012	-.105
	.5	-.069	-.080	.032	.012	-.106
	1.0	-.074	-.079	.031	.013	-.108
7.500	0.0	-.070	-.082	.034	.012	-.107
	.5	-.072	-.082	.033	.012	-.108
	1.0	-.076	-.081	.033	.013	-.111
9.375	0.0	-.074	-.085	.037	.011	-.111
	.5	-.076	-.085	.036	.012	-.112
	1.0	-.080	-.083	.035	.013	-.115
12.500	0.0	-.078	-.088	.039	.011	-.115
	.5	-.079	-.088	.039	.012	-.116
	1.0	-.084	-.086	.038	.013	-.120
16.667	0.0	-.081	-.090	.042	.011	-.119
	.5	-.082	-.090	.041	.011	-.120
	1.0	-.087	-.088	.040	.013	-.123
25.000	0.0	-.084	-.093	.044	.011	-.122
	.5	-.085	-.092	.043	.011	-.123
	1.0	-.091	-.091	.042	.012	-.127
OPEN	0.0					-.121

TABLE I.- UPWASH INTERFERENCE FACTORS δ IN RECTANGULAR TEST SECTIONS CALCULATED BY APPROXIMATION PROCEDURE WITH VARYING PERMEABILITY FACTORS FOR WING-SPAN—TEST-SECTION-WIDTH RATIO s/b OF 0.3 - Continued

(c) Tunnel width-height ratio b/h of 1.00

R/β	y/s	δ_2	δ_3	δ_4	δ_5	Approximated δ $(\delta_2 + \delta_3 + \delta_4 + \delta_5)$
CLOSED	0.0					.138
.100	0.0	.102	.053	-.042	.004	.117
	.5	.104	.052	-.042	.004	.118
	1.0	.108	.049	-.040	.004	.121
.125	0.0	.097	.050	-.039	.004	.112
	.5	.098	.049	-.039	.004	.113
	1.0	.103	.046	-.038	.004	.115
.167	0.0	.089	.046	-.036	.004	.103
	.5	.090	.045	-.035	.004	.104
	1.0	.094	.042	-.034	.005	.107
.222	0.0	.079	.040	-.031	.004	.092
	.5	.081	.039	-.031	.005	.093
	1.0	.084	.036	-.030	.005	.096
.333	0.0	.063	.029	-.025	.005	.072
	.5	.064	.028	-.024	.005	.073
	1.0	.068	.026	-.024	.006	.075
.450	0.0	.050	.017	-.020	.005	.053
	.5	.051	.017	-.019	.006	.054
	1.0	.053	.015	-.019	.006	.056
.562	0.0	.039	.007	-.015	.006	.037
	.5	.040	.007	-.015	.006	.037
	1.0	.042	.005	-.015	.007	.039
.750	0.0	.025	-.008	-.010	.006	.014
	.5	.025	-.008	-.010	.007	.014
	1.0	.027	-.009	-.010	.007	.015
1.000	0.0	.010	-.024	-.004	.007	-.011
	.5	.011	-.024	-.004	.007	-.011
	1.0	.011	-.025	-.004	.008	-.010
1.500	0.0	-.009	-.048	.005	.008	-.044
	.5	-.009	-.048	.005	.008	-.044
	1.0	-.009	-.048	.004	.009	-.043
2.000	0.0	-.020	-.064	.011	.008	-.065
	.5	-.021	-.063	.011	.008	-.065
	1.0	-.022	-.063	.011	.009	-.064
2.500	0.0	-.028	-.075	.016	.008	-.079
	.5	-.029	-.074	.016	.008	-.079
	1.0	-.030	-.073	.015	.009	-.079
3.333	0.0	-.037	-.087	.022	.008	-.094
	.5	-.037	-.086	.021	.008	-.094
	1.0	-.040	-.084	.021	.009	-.094
4.444	0.0	-.044	-.096	.028	.008	-.105
	.5	-.045	-.096	.028	.008	-.104
	1.0	-.047	-.093	.027	.009	-.104
6.667	0.0	-.051	-.107	.034	.007	-.117
	.5	-.052	-.106	.033	.007	-.117
	1.0	-.055	-.103	.033	.009	-.117
7.500	0.0	-.053	-.109	.035	.007	-.120
	.5	-.054	-.108	.035	.007	-.120
	1.0	-.057	-.105	.034	.009	-.119
9.375	0.0	-.056	-.113	.038	.007	-.124
	.5	-.057	-.112	.038	.007	-.124
	1.0	-.060	-.109	.037	.009	-.123
12.500	0.0	-.058	-.117	.041	.006	-.128
	.5	-.060	-.116	.041	.007	-.128
	1.0	-.063	-.112	.040	.008	-.128
16.667	0.0	-.061	-.120	.043	.006	-.131
	.5	-.062	-.119	.043	.007	-.131
	1.0	-.066	-.115	.042	.008	-.131
25.000	0.0	-.063	-.123	.045	.006	-.135
	.5	-.064	-.122	.045	.006	-.135
	1.0	-.068	-.118	.044	.008	-.134
OPEN	0.0					-.136

TABLE I.- UPWASH INTERFERENCE FACTORS δ IN RECTANGULAR TEST SECTIONS CALCULATED BY APPROXIMATION PROCEDURE WITH VARYING PERMEABILITY FACTORS FOR WING-SPAN—TEST-SECTION-WIDTH RATIO s/b OF 0.3 - Continued

(d) Tunnel width-height ratio b/h of 1.50

R/β	y/s	δ_2	δ_3	δ_4	δ_5	Approximated δ $(\delta_2 + \delta_3 + \delta_4 + \delta_5)$
CLOSED	0.0					.116
.100	0.0	.068	.077	-.048	.003	.100
	.5	.069	.074	-.048	.003	.098
	1.0	.072	.065	-.047	.004	.094
.125	0.0	.065	.073	-.045	.003	.095
	.5	.066	.070	-.045	.003	.094
	1.0	.068	.061	-.044	.004	.089
.167	0.0	.059	.066	-.041	.003	.087
	.5	.060	.063	-.041	.003	.086
	1.0	.063	.055	-.040	.004	.082
.222	0.0	.053	.058	-.037	.003	.077
	.5	.054	.055	-.037	.003	.075
	1.0	.056	.047	-.036	.004	.072
.333	0.0	.042	.041	-.030	.003	.057
	.5	.043	.039	-.029	.004	.056
	1.0	.045	.032	-.029	.004	.052
.450	0.0	.033	.024	-.023	.003	.038
	.5	.034	.022	-.023	.004	.037
	1.0	.036	.017	-.023	.004	.034
.562	0.0	.026	.010	-.019	.003	.021
	.5	.027	.008	-.019	.004	.020
	1.0	.028	.003	-.018	.004	.018
.750	0.0	.016	-.012	-.012	.004	-.004
	.5	.017	-.013	-.012	.004	-.005
	1.0	.018	-.017	-.012	.005	-.006
1.000	0.0	.007	-.037	-.005	.004	-.032
	.5	.007	-.037	-.005	.004	-.032
	1.0	.008	-.039	-.005	.005	-.032
1.500	0.0	-.006	-.072	.004	.003	-.070
	.5	-.006	-.071	.004	.004	-.069
	1.0	-.006	-.070	.004	.005	-.068
2.000	0.0	-.014	-.095	.011	.003	-.095
	.5	-.014	-.094	.011	.004	-.093
	1.0	-.015	-.091	.011	.005	-.090
2.500	0.0	-.019	-.111	.015	.003	-.112
	.5	-.019	-.109	.015	.003	-.110
	1.0	-.020	-.105	.015	.005	-.106
3.333	0.0	-.025	-.128	.020	.003	-.130
	.5	-.025	-.126	.020	.003	-.129
	1.0	-.026	-.121	.020	.004	-.123
4.444	0.0	-.029	-.143	.025	.003	-.144
	.5	-.030	-.140	.025	.003	-.142
	1.0	-.031	-.133	.025	.004	-.136
6.667	0.0	-.034	-.158	.029	.002	-.160
	.5	-.035	-.155	.029	.003	-.158
	1.0	-.037	-.146	.030	.004	-.150
7.500	0.0	-.035	-.161	.030	.002	-.164
	.5	-.036	-.158	.030	.002	-.161
	1.0	-.038	-.149	.031	.004	-.153
9.375	0.0	-.037	-.167	.033	.002	-.169
	.5	-.038	-.163	.033	.002	-.166
	1.0	-.040	-.154	.033	.003	-.158
12.500	0.0	-.039	-.172	.035	.002	-.175
	.5	-.040	-.169	.035	.002	-.172
	1.0	-.042	-.159	.035	.003	-.163
16.667	0.0	-.040	-.177	.036	.002	-.180
	.5	-.041	-.173	.036	.002	-.176
	1.0	-.044	-.163	.037	.003	-.167
25.000	0.0	-.042	-.181	.037	.001	-.184
	.5	-.043	-.177	.038	.002	-.181
	1.0	-.045	-.167	.038	.003	-.171
OPEN	0.0					-.191

TABLE I.- UPWASH INTERFERENCE FACTORS δ IN RECTANGULAR TEST SECTIONS CALCULATED BY APPROXIMATION PROCEDURE WITH VARYING PERMEABILITY FACTORS FOR WING-SPAN—TEST-SECTION-WIDTH RATIO s/b OF 0.3 - Concluded

(e) Tunnel width-height ratio b/h of 2.00

R/β	y/s	δ_2	δ_3	δ_4	δ_5	Approximated δ $(\delta_2 + \delta_3 + \delta_4 + \delta_5)$
CLOSED	0.0					.125
.100	0.0	.051	.098	-.044	.002	.106
	.5	.052	.091	-.044	.002	.101
	1.0	.054	.074	-.044	.002	.086
.125	0.0	.049	.093	-.042	.002	.101
	.5	.049	.086	-.042	.002	.096
	1.0	.051	.069	-.041	.002	.082
.167	0.0	.044	.084	-.038	.002	.092
	.5	.045	.078	-.038	.002	.087
	1.0	.047	.062	-.038	.002	.073
.222	0.0	.040	.073	-.034	.002	.080
	.5	.040	.067	-.034	.002	.075
	1.0	.042	.052	-.034	.002	.063
.333	0.0	.032	.051	-.027	.002	.057
	.5	.032	.046	-.027	.002	.053
	1.0	.034	.033	-.027	.002	.042
.450	0.0	.025	.030	-.022	.002	.034
	.5	.025	.026	-.022	.002	.031
	1.0	.027	.015	-.022	.002	.022
.562	0.0	.020	.010	-.017	.002	.014
	.5	.020	.007	-.017	.002	.012
	1.0	.021	-.002	-.017	.002	.005
.750	0.0	.012	-.018	-.011	.002	-.015
	.5	.013	-.020	-.011	.002	-.017
	1.0	.013	-.026	-.011	.002	-.022
1.000	0.0	.005	-.050	-.005	.002	-.048
	.5	.005	-.051	-.005	.002	-.049
	1.0	.006	-.053	-.005	.002	-.050
1.500	0.0	-.004	-.095	.004	.001	-.094
	.5	-.004	-.094	.004	.002	-.093
	1.0	-.005	-.092	.004	.002	-.090
2.000	0.0	-.010	-.125	.009	.001	-.125
	.5	-.010	-.123	.009	.001	-.122
	1.0	-.011	-.116	.009	.002	-.116
2.500	0.0	-.014	-.146	.013	.001	-.146
	.5	-.014	-.142	.013	.001	-.142
	1.0	-.015	-.133	.013	.002	-.133
3.333	0.0	-.018	-.158	.017	.001	-.169
	.5	-.019	-.164	.017	.001	-.165
	1.0	-.020	-.152	.017	.002	-.153
4.444	0.0	-.022	-.187	.021	.001	-.187
	.5	-.022	-.181	.021	.001	-.182
	1.0	-.024	-.167	.021	.002	-.167
6.667	0.0	-.026	-.206	.024	.001	-.207
	.5	-.026	-.200	.024	.001	-.201
	1.0	-.028	-.182	.025	.001	-.184
7.500	0.0	-.026	-.210	.025	.001	-.211
	.5	-.027	-.204	.025	.001	-.205
	1.0	-.029	-.186	.026	.001	-.187
9.375	0.0	-.028	-.218	.026	.001	-.218
	.5	-.028	-.211	.027	.001	-.212
	1.0	-.030	-.192	.028	.001	-.193
12.500	0.0	-.029	-.225	.028	.000	-.226
	.5	-.030	-.218	.028	.001	-.219
	1.0	-.032	-.197	.029	.001	-.199
16.667	0.0	-.030	-.230	.029	.000	-.231
	.5	-.031	-.223	.029	.001	-.224
	1.0	-.033	-.202	.030	.001	-.203
25.000	0.0	-.031	-.236	.030	.000	-.237
	.5	-.032	-.228	.030	.000	-.229
	1.0	-.034	-.206	.032	.001	-.208
OPEN	0.0					-.248

TABLE II.- UPWASH INTERFERENCE FACTORS δ IN RECTANGULAR TEST SECTIONS CALCULATED BY APPROXIMATION PROCEDURE WITH VARYING PERMEABILITY FACTORS FOR WING-SPAN—TEST-SECTION-WIDTH RATIO s/b OF 0.7

(a) Tunnel width-height ratio b/h of 0.50

R/β	y/s	δ_2	δ_3	δ_4	δ_5	Approximated δ $(\delta_2 + \delta_3 + \delta_4 + \delta_5)$
CLOSED	0.0					.286
.100	0.0	.223	.026	-.012	-.003	.234
	.5	.246	.026	-.012	-.003	.256
	1.0	.344	.024	-.011	-.002	.354
.125	0.0	.211	.025	-.011	-.002	.223
	.5	.234	.024	-.010	-.002	.245
	1.0	.330	.022	-.010	-.002	.340
.167	0.0	.194	.023	-.008	-.002	.207
	.5	.215	.022	-.008	-.002	.228
	1.0	.307	.020	-.008	-.001	.318
.222	0.0	.174	.020	-.006	-.001	.187
	.5	.194	.019	-.006	-.001	.206
	1.0	.279	.017	-.006	-.000	.290
.333	0.0	.140	.014	-.004	.001	.151
	.5	.157	.014	-.004	.001	.168
	1.0	.230	.012	-.003	.001	.240
.450	0.0	.111	.009	-.002	.003	.119
	.5	.125	.008	-.002	.003	.133
	1.0	.186	.007	-.002	.003	.194
.562	0.0	.087	.004	-.002	.004	.093
	.5	.099	.003	-.002	.004	.104
	1.0	.150	.002	-.001	.004	.155
.750	0.0	.055	-.004	-.001	.006	.057
	.5	.064	-.004	-.001	.006	.065
	1.0	.099	-.005	-.001	.007	.100
1.000	0.0	.024	-.012	.000	.008	.020
	.5	.028	-.012	.000	.008	.024
	1.0	.045	-.013	.001	.009	.042
1.500	0.0	-.019	-.024	.004	.011	-.027
	.5	-.021	-.024	.004	.012	-.029
	1.0	-.029	-.024	.004	.012	-.036
2.000	0.0	-.045	-.032	.008	.013	-.056
	.5	-.051	-.032	.008	.014	-.061
	1.0	-.076	-.031	.007	.015	-.086
2.500	0.0	-.063	-.037	.011	.014	-.075
	.5	-.072	-.037	.011	.015	-.083
	1.0	-.109	-.036	.010	.016	-.119
3.333	0.0	-.082	-.043	.015	.015	-.095
	.5	-.094	-.043	.015	.016	-.106
	1.0	-.146	-.042	.013	.017	-.157
4.444	0.0	-.098	-.048	.020	.016	-.110
	.5	-.113	-.047	.019	.017	-.124
	1.0	-.175	-.046	.017	.018	-.186
6.667	0.0	-.115	-.053	.024	.017	-.127
	.5	-.132	-.052	.023	.017	-.144
	1.0	-.208	-.051	.021	.019	-.218
7.500	0.0	-.119	-.054	.025	.017	-.131
	.5	-.137	-.054	.024	.018	-.149
	1.0	-.215	-.052	.022	.020	-.226
9.375	0.0	-.125	-.056	.028	.017	-.137
	.5	-.144	-.056	.027	.018	-.155
	1.0	-.227	-.053	.024	.020	-.237
12.500	0.0	-.132	-.058	.030	.017	-.143
	.5	-.152	-.057	.029	.018	-.163
	1.0	-.240	-.055	.025	.020	-.249
16.667	0.0	-.137	-.060	.031	.017	-.148
	.5	-.158	-.059	.031	.018	-.168
	1.0	-.249	-.057	.027	.020	-.259
25.000	0.0	-.142	-.061	.033	.017	-.153
	.5	-.164	-.060	.032	.018	-.174
	1.0	-.259	-.058	.028	.021	-.268
OPEN	0.0					-.157

TABLE II.- UPWASH INTERFERENCE FACTORS δ IN RECTANGULAR TEST SECTIONS CALCULATED BY APPROXIMATION PROCEDURE WITH VARYING PERMEABILITY FACTORS FOR WING-SPAN—TEST-SECTION-WIDTH RATIO s/b OF 0.7 - Continued

(b) Tunnel width-height ratio b/h of 0.75

R/β	y/s	δ_2	δ_3	δ_4	δ_5	Approximated δ $(\delta_2 + \delta_3 + \delta_4 + \delta_5)$
CLOSED	0.0					.191
.100	0.0	.148	.038	-.028	.001	.159
	.5	.164	.036	-.027	.001	.173
	1.0	.230	.030	-.023	.001	.238
.125	0.0	.141	.036	-.026	.001	.152
	.5	.156	.034	-.025	.001	.166
	1.0	.220	.028	-.021	.002	.228
.167	0.0	.129	.032	-.023	.002	.141
	.5	.144	.030	-.022	.002	.154
	1.0	.204	.025	-.019	.002	.213
.222	0.0	.116	.028	-.019	.002	.127
	.5	.129	.026	-.018	.002	.139
	1.0	.186	.022	-.016	.003	.194
.333	0.0	.093	.020	-.015	.003	.102
	.5	.104	.018	-.014	.004	.112
	1.0	.153	.014	-.012	.004	.160
.450	0.0	.074	.012	-.011	.004	.078
	.5	.083	.010	-.011	.005	.088
	1.0	.124	.007	-.009	.006	.128
.562	0.0	.058	.004	-.009	.005	.059
	.5	.066	.003	-.008	.006	.067
	1.0	.100	.000	-.007	.007	.100
.750	0.0	.037	-.006	-.006	.007	.032
	.5	.042	-.007	-.005	.007	.037
	1.0	.066	-.009	-.004	.009	.061
1.000	0.0	.016	-.018	-.002	.008	.004
	.5	.018	-.019	-.002	.009	.007
	1.0	.030	-.020	-.001	.011	.020
1.500	0.0	-.012	-.036	.005	.010	-.033
	.5	-.014	-.036	.005	.011	-.034
	1.0	-.019	-.035	.004	.013	-.036
2.000	0.0	-.030	-.047	.011	.011	-.056
	.5	-.034	-.047	.010	.012	-.058
	1.0	-.051	-.045	.009	.015	-.071
2.500	0.0	-.042	-.055	.015	.012	-.070
	.5	-.048	-.054	.015	.013	-.074
	1.0	-.073	-.051	.013	.016	-.095
3.333	0.0	-.055	-.064	.021	.012	-.086
	.5	-.063	-.062	.020	.013	-.092
	1.0	-.097	-.059	.018	.017	-.121
4.444	0.0	-.065	-.071	.028	.012	-.097
	.5	-.075	-.069	.026	.014	-.104
	1.0	-.117	-.065	.023	.018	-.141
6.667	0.0	-.077	-.078	.034	.012	-.109
	.5	-.088	-.076	.032	.014	-.118
	1.0	-.133	-.071	.028	.019	-.163
7.500	0.0	-.079	-.080	.035	.012	-.112
	.5	-.091	-.078	.034	.014	-.122
	1.0	-.143	-.072	.029	.019	-.168
9.375	0.0	-.084	-.083	.038	.012	-.116
	.5	-.096	-.080	.036	.014	-.126
	1.0	-.151	-.075	.031	.019	-.175
12.500	0.0	-.088	-.085	.041	.011	-.121
	.5	-.101	-.083	.039	.014	-.131
	1.0	-.160	-.077	.034	.020	-.184
16.667	0.0	-.091	-.087	.043	.011	-.124
	.5	-.105	-.085	.041	.013	-.135
	1.0	-.166	-.079	.035	.020	-.190
25.000	0.0	-.095	-.090	.046	.011	-.128
	.5	-.109	-.087	.044	.013	-.139
	1.0	-.173	-.080	.037	.020	-.196
OPEN	0.0					-.128

TABLE II.- UPWASH INTERFERENCE FACTORS δ IN RECTANGULAR TEST SECTIONS CALCULATED BY APPROXIMATION PROCEDURE WITH VARYING PERMEABILITY FACTORS FOR WING-SPAN—TEST-SECTION-WIDTH RATIO s/b OF 0.7 - Continued

(c) Tunnel width-height ratio b/h of 1.00

R/β	y/s	δ_2	δ_3	δ_4	δ_5	Approximated δ $(\delta_2 + \delta_3 + \delta_4 + \delta_5)$
CLOSED	0.0					.145
.100	0.0	.111	.047	-.039	.002	.122
	.5	.123	.043	-.037	.003	.132
	1.0	.172	.033	-.030	.004	.178
.125	0.0	.106	.045	-.036	.003	.116
	.5	.117	.041	-.034	.003	.126
	1.0	.165	.031	-.028	.004	.171
.167	0.0	.097	.040	-.033	.003	.107
	.5	.108	.037	-.031	.003	.117
	1.0	.153	.027	-.026	.005	.159
.222	0.0	.087	.035	-.029	.003	.096
	.5	.097	.031	-.027	.004	.105
	1.0	.139	.022	-.022	.005	.145
.333	0.0	.070	.024	-.023	.004	.075
	.5	.078	.021	-.021	.004	.083
	1.0	.115	.014	-.018	.006	.117
.450	0.0	.055	.014	-.018	.005	.055
	.5	.062	.011	-.017	.005	.062
	1.0	.093	.005	-.014	.007	.091
.562	0.0	.044	.004	-.014	.005	.039
	.5	.049	.002	-.014	.006	.044
	1.0	.075	-.003	-.011	.008	.069
.750	0.0	.028	-.010	-.009	.006	.015
	.5	.032	-.011	-.009	.007	.019
	1.0	.049	-.014	-.007	.010	.038
1.000	0.0	.012	-.025	-.004	.007	-.010
	.5	.014	-.026	-.003	.008	-.007
	1.0	.023	-.027	-.003	.011	.004
1.500	0.0	-.009	-.047	.005	.008	-.044
	.5	-.010	-.047	.005	.009	-.043
	1.0	-.014	-.045	.004	.013	-.041
2.000	0.0	-.023	-.062	.012	.008	-.065
	.5	-.025	-.061	.011	.010	-.065
	1.0	-.033	-.056	.010	.015	-.070
2.500	0.0	-.031	-.072	.017	.008	-.078
	.5	-.036	-.070	.016	.010	-.079
	1.0	-.055	-.064	.014	.015	-.089
3.333	0.0	-.041	-.083	.023	.008	-.093
	.5	-.047	-.080	.022	.010	-.095
	1.0	-.073	-.073	.019	.016	-.110
4.444	0.0	-.049	-.092	.030	.008	-.103
	.5	-.055	-.089	.029	.010	-.106
	1.0	-.088	-.080	.025	.017	-.125
6.667	0.0	-.058	-.101	.036	.007	-.115
	.5	-.065	-.097	.035	.010	-.119
	1.0	-.104	-.087	.030	.018	-.143
7.500	0.0	-.059	-.103	.038	.007	-.118
	.5	-.068	-.099	.036	.010	-.122
	1.0	-.108	-.088	.032	.018	-.147
9.375	0.0	-.063	-.107	.041	.007	-.122
	.5	-.072	-.103	.039	.010	-.126
	1.0	-.114	-.091	.034	.018	-.153
12.500	0.0	-.066	-.111	.044	.007	-.126
	.5	-.076	-.106	.042	.009	-.130
	1.0	-.120	-.094	.037	.018	-.159
16.667	0.0	-.068	-.113	.046	.006	-.129
	.5	-.079	-.108	.045	.009	-.133
	1.0	-.125	-.096	.039	.018	-.164
25.000	0.0	-.071	-.116	.048	.006	-.132
	.5	-.082	-.111	.047	.009	-.137
	1.0	-.130	-.098	.041	.018	-.169
OPEN	0.0					-.134

TABLE II.- UPWASH INTERFERENCE FACTORS δ IN RECTANGULAR TEST SECTIONS CALCULATED BY APPROXIMATION PROCEDURE WITH VARYING PERMEABILITY FACTORS FOR WING-SPAN—TEST-SECTION-WIDTH RATIO s/b OF 0.7 - Continued

(d) Tunnel width-height ratio b/h of 1.50

R/β	y/s	δ_2	δ_3	δ_4	δ_5	Approximated δ $(\delta_2 + \delta_3 + \delta_4 + \delta_5)$
CLOSED	0.0					.106
.100	0.0	.074	.060	-.047	.002	.089
	.5	.082	.052	-.045	.003	.092
	1.0	.115	.031	-.036	.006	.116
.125	0.0	.070	.056	-.045	.002	.085
	.5	.078	.048	-.042	.003	.087
	1.0	.110	.028	-.034	.006	.110
.167	0.0	.065	.051	-.041	.003	.077
	.5	.072	.043	-.039	.003	.080
	1.0	.102	.024	-.031	.007	.102
.222	0.0	.058	.043	-.036	.003	.067
	.5	.065	.036	-.034	.004	.070
	1.0	.093	.019	-.028	.007	.090
.333	0.0	.047	.028	-.029	.003	.049
	.5	.052	.023	-.028	.004	.051
	1.0	.077	.008	-.023	.008	.070
.450	0.0	.037	.014	-.023	.003	.030
	.5	.042	.009	-.022	.004	.033
	1.0	.062	-.002	-.018	.008	.050
.562	0.0	.029	.001	-.019	.003	.015
	.5	.033	-.003	-.018	.004	.017
	1.0	.050	-.012	-.015	.009	.032
.750	0.0	.019	-.018	-.012	.003	-.009
	.5	.021	-.020	-.012	.005	-.006
	1.0	.033	-.025	-.010	.010	.008
1.000	0.0	.008	-.039	-.005	.004	-.033
	.5	.009	-.040	-.005	.005	-.030
	1.0	.015	-.040	-.004	.011	-.019
1.500	0.0	-.006	-.070	.005	.004	-.068
	.5	-.007	-.067	.005	.005	-.064
	1.0	-.010	-.061	.004	.012	-.055
2.000	0.0	-.015	-.089	.012	.003	-.089
	.5	-.017	-.085	.011	.005	-.085
	1.0	-.025	-.074	.010	.013	-.077
2.500	0.0	-.021	-.103	.016	.003	-.104
	.5	-.024	-.097	.016	.005	-.099
	1.0	-.036	-.083	.015	.013	-.092
3.333	0.0	-.027	-.117	.022	.003	-.120
	.5	-.031	-.111	.022	.005	-.115
	1.0	-.049	-.093	.020	.013	-.108
4.444	0.0	-.033	-.129	.028	.003	-.132
	.5	-.038	-.121	.028	.005	-.126
	1.0	-.058	-.100	.026	.014	-.119
6.667	0.0	-.038	-.142	.032	.002	-.145
	.5	-.044	-.132	.033	.005	-.139
	1.0	-.069	-.108	.031	.014	-.132
7.500	0.0	-.040	-.144	.034	.002	-.148
	.5	-.046	-.135	.034	.005	-.142
	1.0	-.072	-.110	.033	.014	-.135
9.375	0.0	-.042	-.149	.036	.002	-.153
	.5	-.049	-.139	.037	.004	-.146
	1.0	-.076	-.113	.035	.014	-.140
12.500	0.0	-.044	-.154	.038	.002	-.157
	.5	-.051	-.143	.040	.004	-.150
	1.0	-.080	-.116	.038	.014	-.144
16.667	0.0	-.046	-.157	.040	.002	-.161
	.5	-.053	-.146	.041	.004	-.154
	1.0	-.083	-.118	.040	.014	-.148
25.000	0.0	-.047	-.161	.042	.001	-.165
	.5	-.055	-.150	.043	.004	-.157
	1.0	-.086	-.120	.042	.013	-.151
OPEN	0.0					-.169

TABLE II.- UPWASH INTERFERENCE FACTORS δ IN RECTANGULAR TEST SECTIONS CALCULATED BY APPROXIMATION PROCEDURE WITH VARYING PERMEABILITY FACTORS FOR WING-SPAN—TEST-SECTION-WIDTH RATIO s/b OF 0.7 - Concluded

(e) Tunnel width-height ratio b/h of 2.00

R/β	y/s	δ_2	δ_3	δ_4	δ_5	Approximated δ $(\delta_2 + \delta_3 + \delta_4 + \delta_5)$
CLOSED	0.0					.094
.100	0.0	.056	.065	-.045	.001	.077
	.5	.061	.054	-.044	.002	.074
	1.0	.086	.025	-.038	.006	.080
.125	0.0	.053	.061	-.043	.001	.072
	.5	.058	.051	-.042	.002	.070
	1.0	.082	.023	-.036	.007	.076
.167	0.0	.049	.054	-.039	.001	.065
	.5	.054	.044	-.038	.002	.062
	1.0	.077	.018	-.033	.007	.069
.222	0.0	.043	.045	-.035	.001	.055
	.5	.048	.036	-.035	.003	.052
	1.0	.070	.012	-.030	.007	.059
.333	0.0	.035	.027	-.029	.002	.035
	.5	.039	.020	-.028	.003	.034
	1.0	.057	.001	-.024	.007	.042
.450	0.0	.028	.010	-.023	.002	.016
	.5	.031	.005	-.022	.003	.016
	1.0	.047	-.010	-.020	.008	.025
.562	0.0	.022	-.006	-.018	.002	-.000
	.5	.025	-.009	-.018	.003	.000
	1.0	.037	-.020	-.016	.008	.010
.750	0.0	.014	-.029	-.012	.002	-.025
	.5	.016	-.030	-.012	.003	-.023
	1.0	.025	-.034	-.011	.008	-.012
1.000	0.0	.006	-.054	-.005	.002	-.051
	.5	.007	-.053	-.005	.003	-.048
	1.0	.011	-.050	-.005	.009	-.035
1.500	0.0	-.005	-.090	.004	.001	-.089
	.5	-.005	-.085	.004	.003	-.083
	1.0	-.007	-.072	.004	.010	-.066
2.000	0.0	-.011	-.113	.010	.001	-.112
	.5	-.013	-.105	.010	.003	-.105
	1.0	-.019	-.086	.010	.010	-.085
2.500	0.0	-.016	-.128	.014	.001	-.129
	.5	-.018	-.119	.015	.003	-.119
	1.0	-.027	-.095	.015	.010	-.098
3.333	0.0	-.021	-.146	.019	.001	-.146
	.5	-.024	-.134	.020	.002	-.136
	1.0	-.036	-.105	.020	.010	-.111
4.444	0.0	-.025	-.159	.023	.001	-.160
	.5	-.028	-.146	.024	.002	-.148
	1.0	-.044	-.113	.025	.010	-.122
6.667	0.0	-.029	-.174	.027	.001	-.175
	.5	-.033	-.159	.029	.002	-.161
	1.0	-.052	-.121	.031	.010	-.132
7.500	0.0	-.030	-.177	.028	.001	-.178
	.5	-.034	-.162	.030	.002	-.164
	1.0	-.054	-.123	.032	.010	-.135
9.375	0.0	-.031	-.182	.030	.001	-.183
	.5	-.036	-.167	.032	.002	-.169
	1.0	-.057	-.126	.035	.010	-.138
12.500	0.0	-.033	-.187	.031	.001	-.188
	.5	-.038	-.171	.034	.002	-.174
	1.0	-.060	-.129	.037	.010	-.142
16.667	0.0	-.034	-.191	.033	.000	-.193
	.5	-.039	-.175	.035	.002	-.177
	1.0	-.062	-.131	.039	.009	-.145
25.000	0.0	-.035	-.195	.034	.000	-.197
	.5	-.041	-.178	.037	.001	-.181
	1.0	-.065	-.133	.041	.009	-.148
OPEN	0.0					-.204

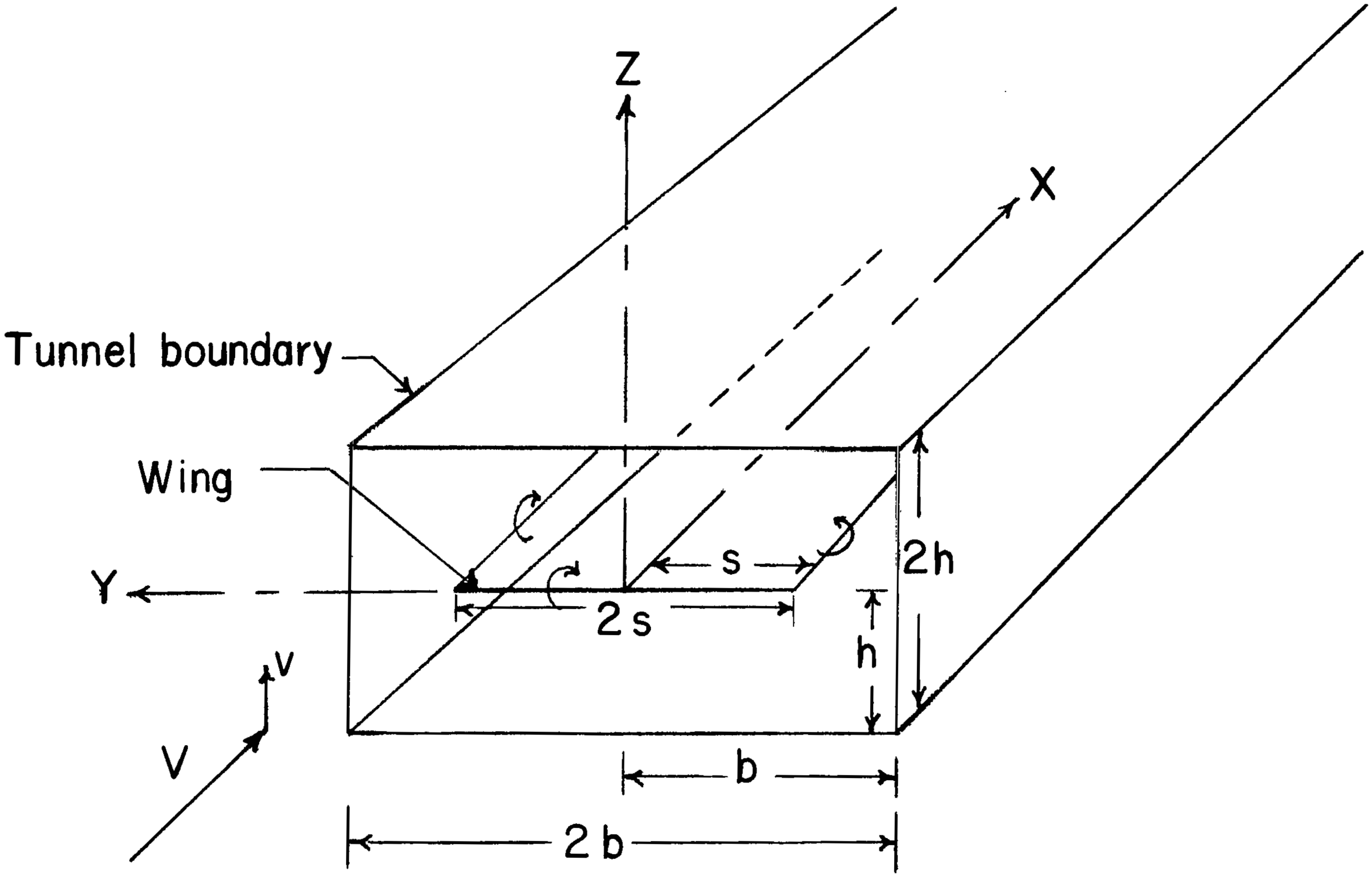


Figure 1.- Schematic diagram showing relationships between various parameters in a rectangular perforated wind tunnel.

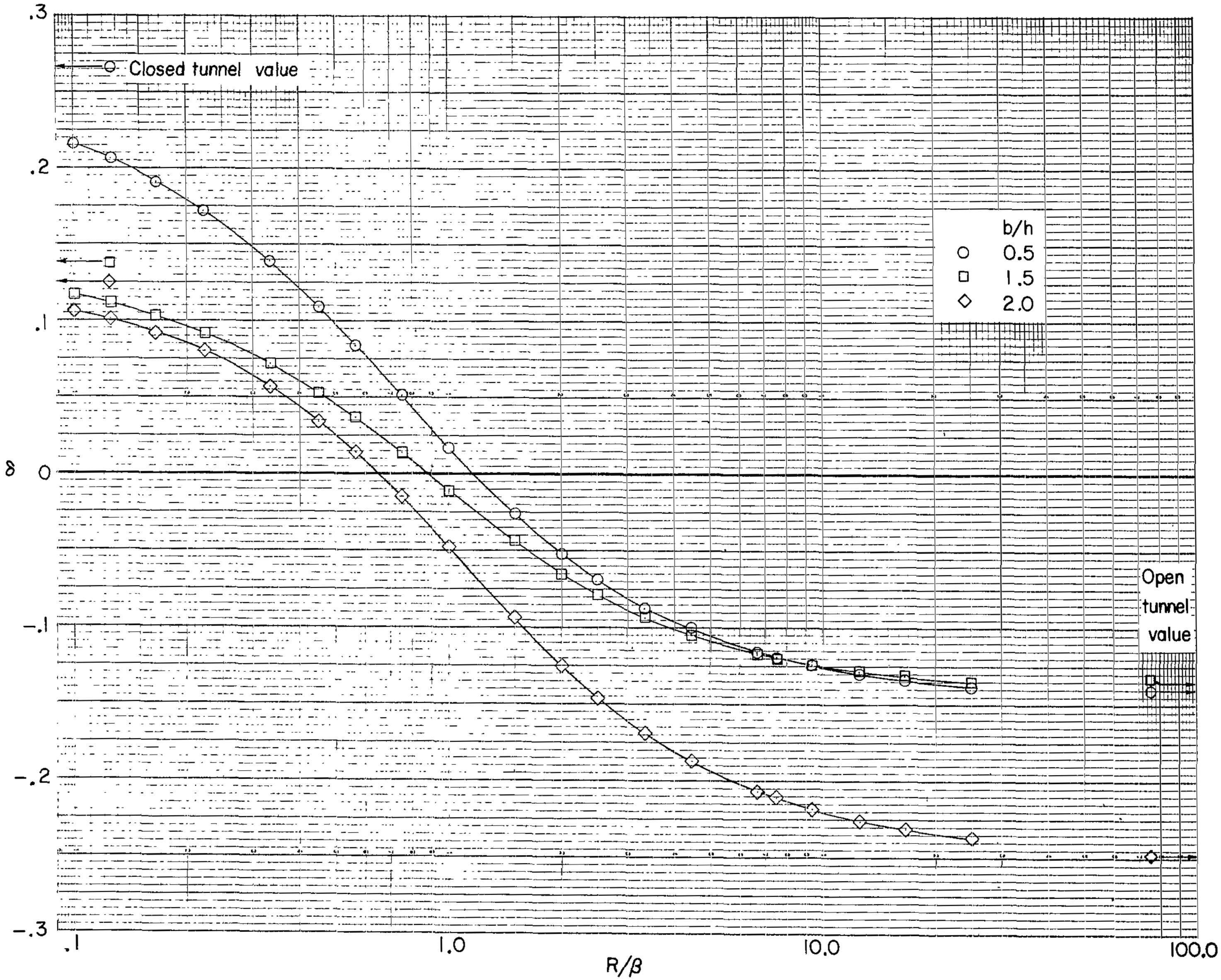


Figure 2.- Calculated total upwash interference factor δ as a function of R/β at the center of a small-span (s/b = 0.3) wing mounted in the center of a rectangular perforated wind tunnel.

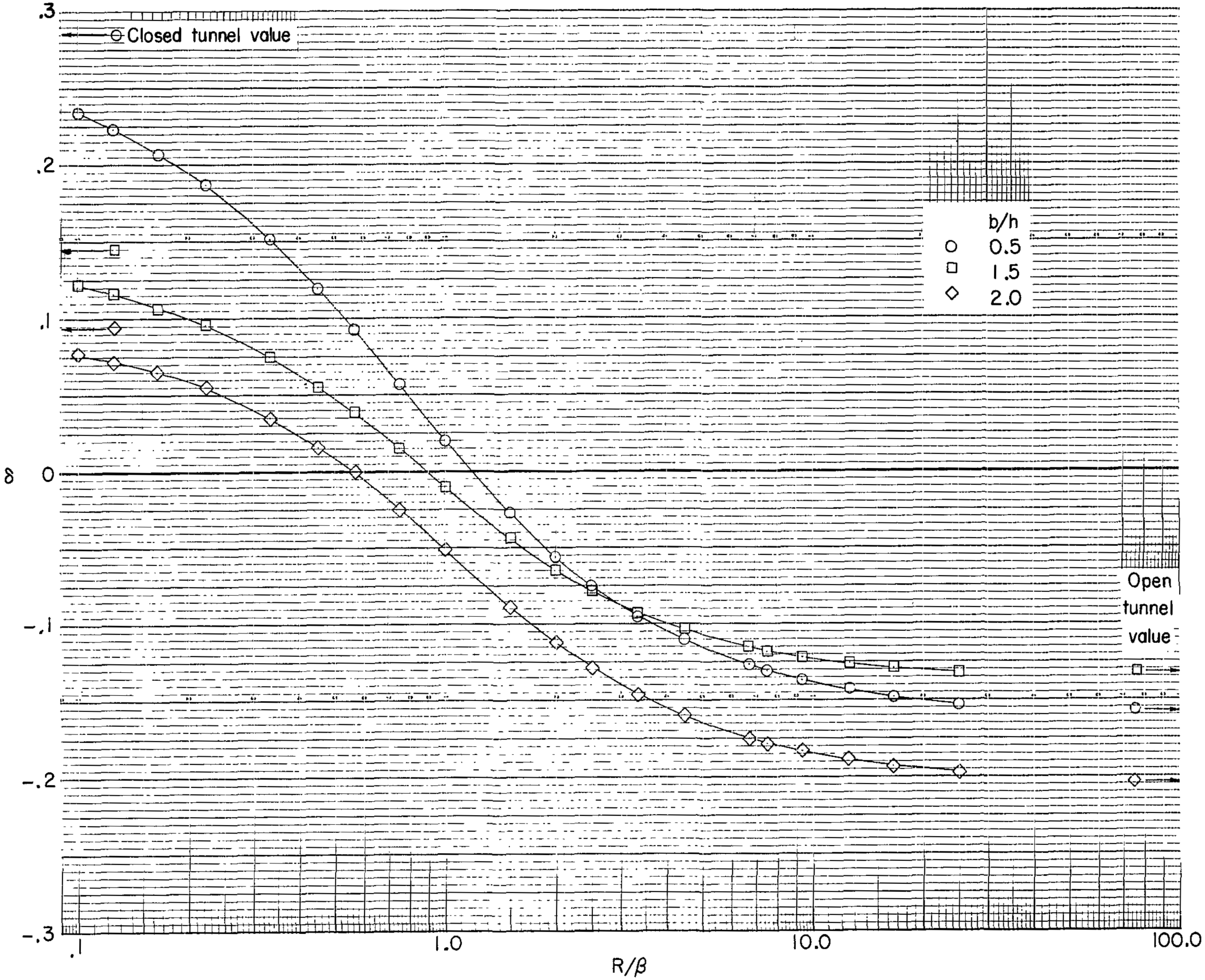
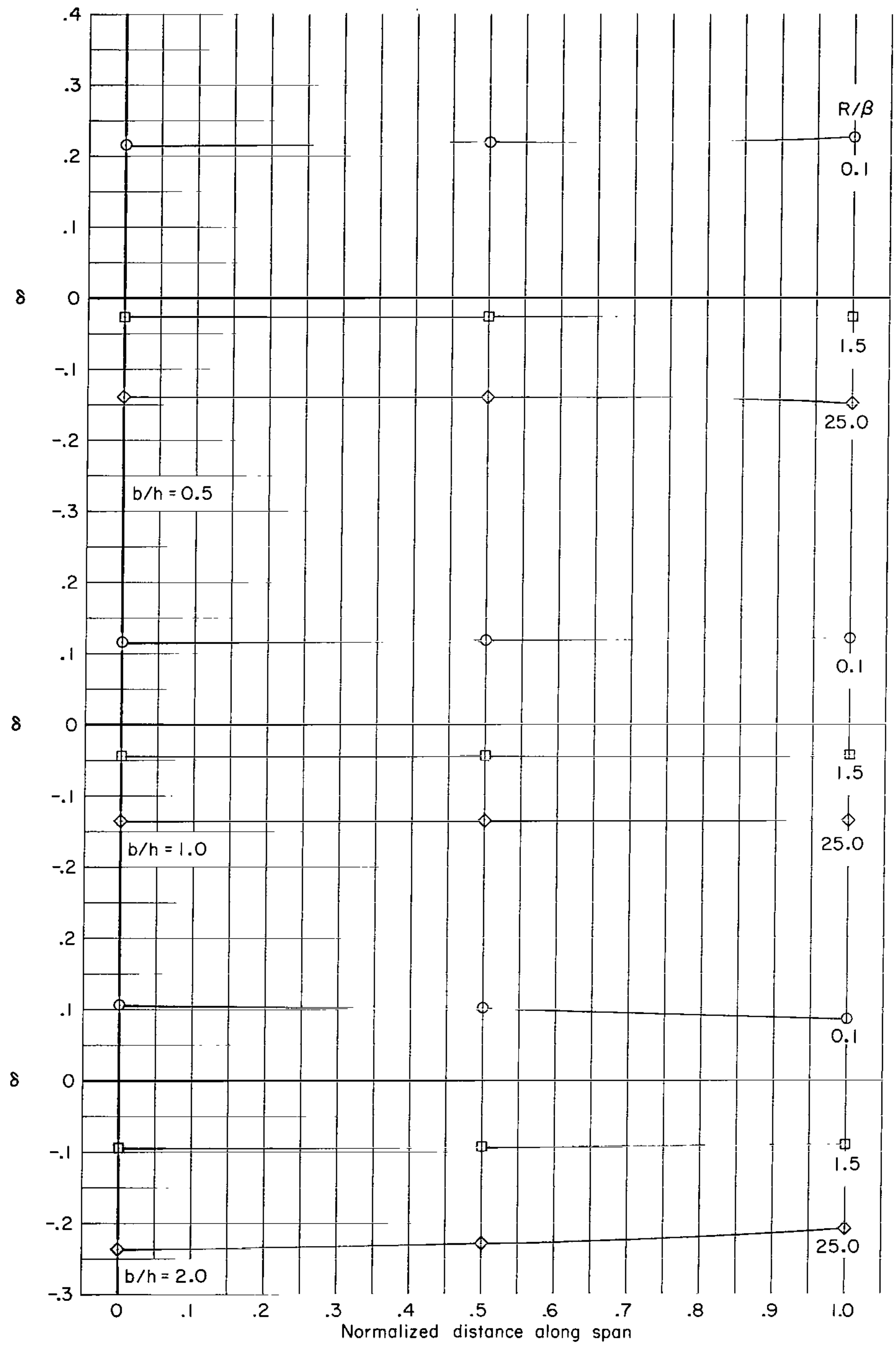
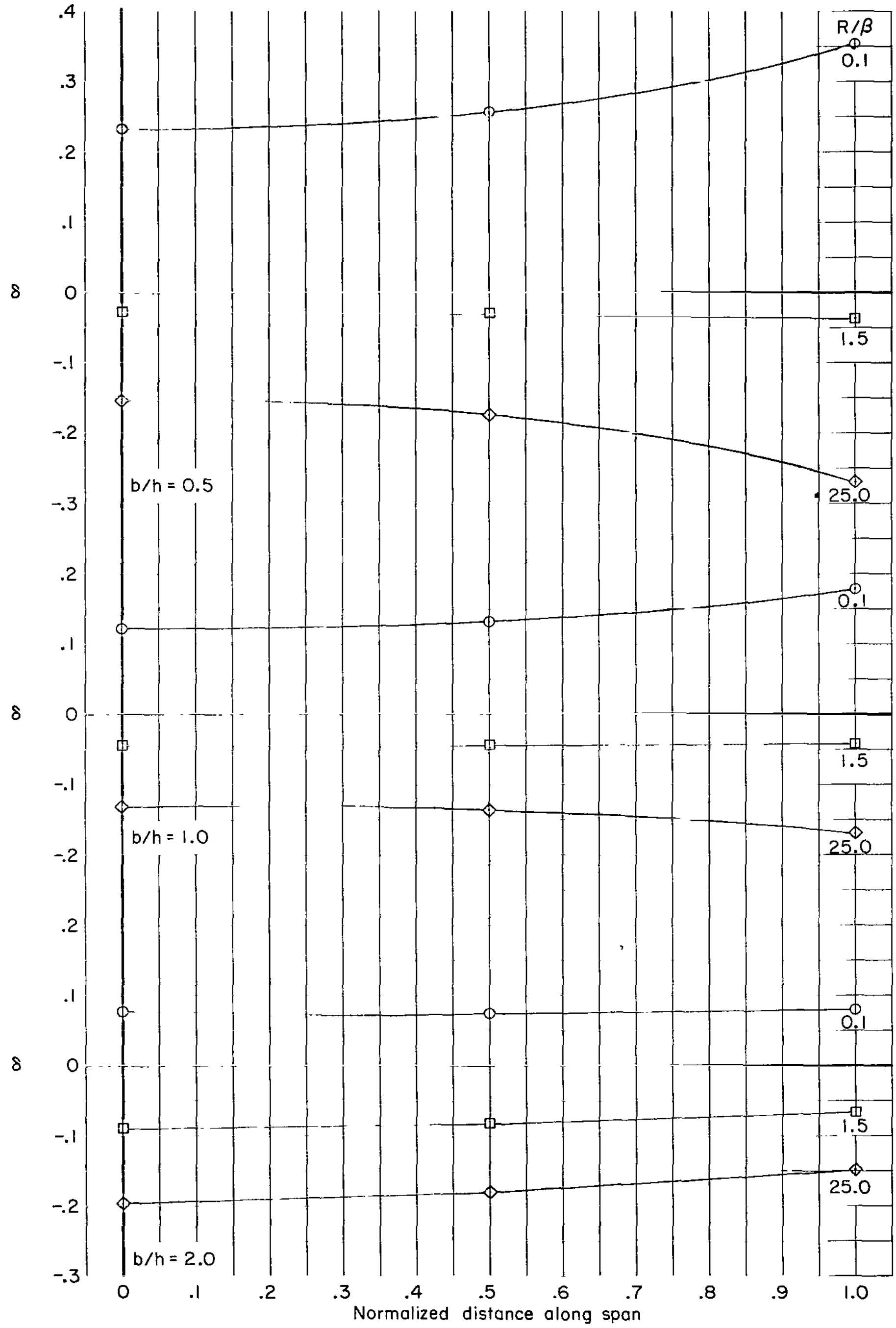


Figure 3.- Calculated total upwash interference factor δ as a function of R/β at the center of a large-span (s/b = 0.7) wing mounted in the center of a rectangular perforated wind tunnel.



(a) s/b = 0.3.

Figure 4.- Variation of total upwash interference factor along the span of a small-span (s/b = 0.3) and a large-span (s/b = 0.7) wing mounted in the center of a rectangular perforated wind tunnel for various tunnel width-height ratios b/h and various permeability factors R/β.



(b) s/b = 0.7.

Figure 4.- Concluded.

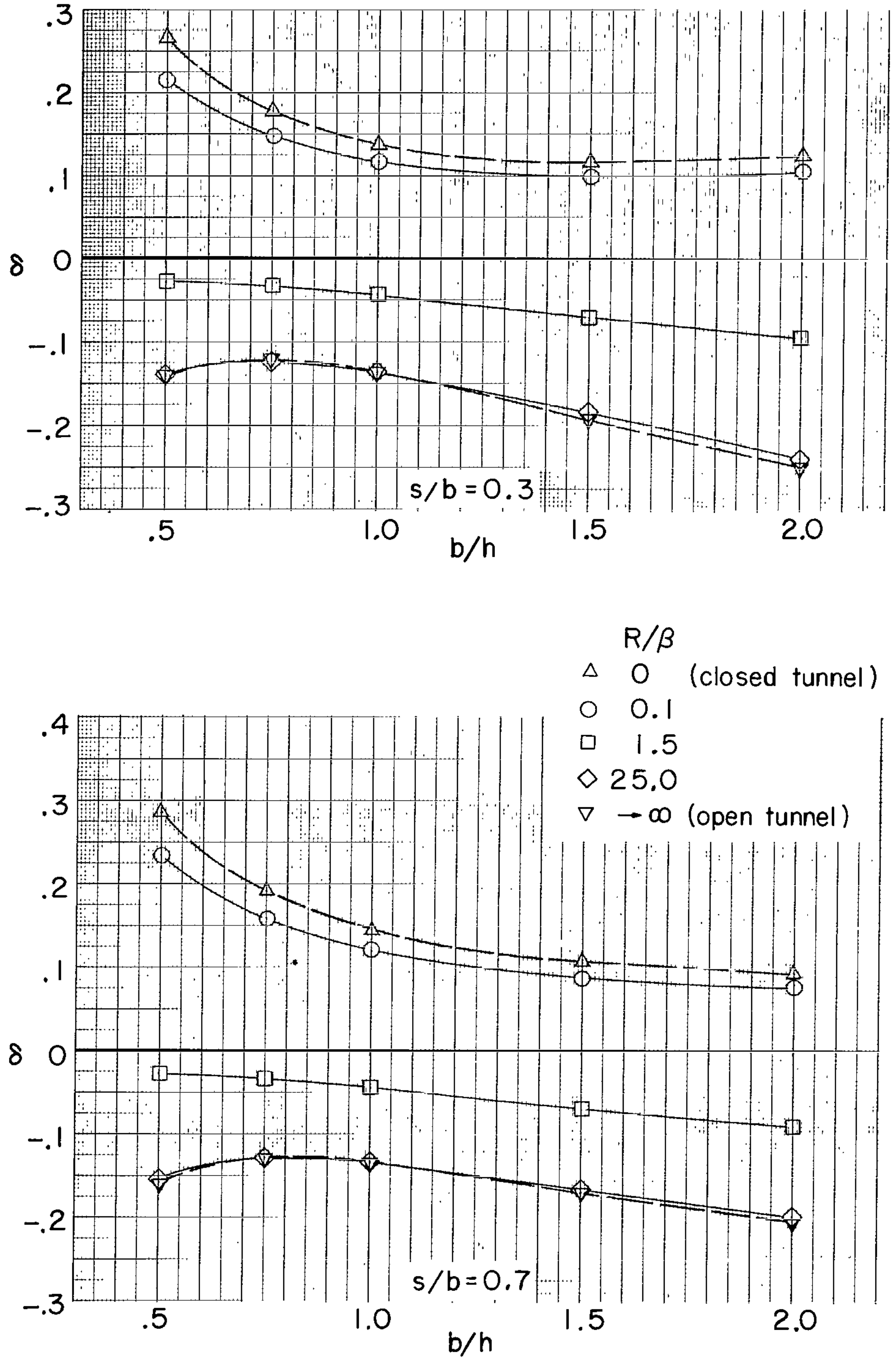


Figure 5.- Calculated total upwash interference factor as a function of tunnel width-height ratio b/h at the center of a small span (s/b = 0.3) and a large-span (s/b = 0.7) wing mounted in the center of a rectangular perforated wind tunnel for three values of R/β.

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